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13. ABSTRACT

The US Army Advanced Materiel Concepts Agency (AMCA) convened an ad hoc working group (AHWG) for 3 days (27-29 April 1971) to survey advanced concepts of strategic transportation. The objective of this study was to identify management problems that might be caused by the exploitation of the fast, high-capacity, versatile transportation envisioned. Seven papers, summarized in appendices of the report, surveyed some of the major technological advances in transportation which may be expected to mature in the next 20 years. With this understanding as a reference, the AHWG was divided into three panels to identify control-center systems requirements related to: (a) advanced technology of transportation; (b) technology related to the materiel shipped and its documentation; and (c) command, control, and communications. Some of the technological concepts discussed were: hypersonic vehicles; nuclear-powered, long-range aircraft; seaplanes; air-cushion and hydrofoil ships; air-cushion vehicles; floating bases; V/STOL aircraft; and dirigibles. The need for electronic labeling and automated documentation of cargo is emphasized. Also, the report points out that the probability of use of hydrogen as a fuel for hypersonic vehicles should stimulate reconsideration of hydrogen as a fuel for ground vehicles in a theater of operations. Finally, the report suggests that dirigibles have been rejected from consideration for the wrong reasons and could, in fact, play an important role in future logistics operations.

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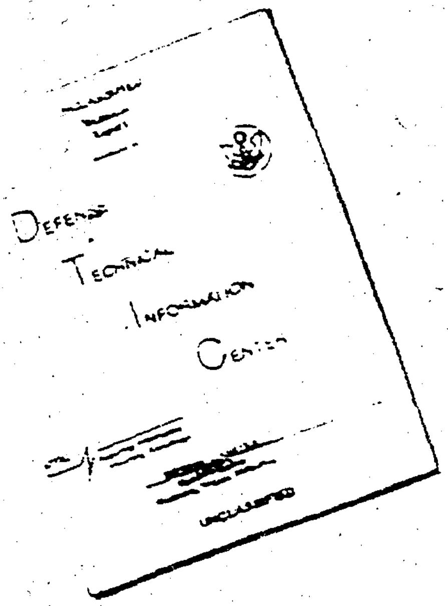

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Report AMCA-72-003

THEATER TRANSPORTATION MANAGEMENT, 1990 - SYSTEM REQUIREMENTS

Report of the Twenty-First Ad Hoc Working Group

January 1972

US Army Advanced Material Concepts Agency
2461 Eisenhower Avenue
Alexandria, Virginia 22314

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AMCA AD HOC WORKING GROUPS COMPLETED AND IN-PROCESS

AHWG Number	Title		AD Number
1	Future Warfare in Urban Areas		867775L
2	Adverse Effects of Slopes on Military Operations		867772L
3	Directed Energy for Military Operations	Matrix	871657L
4	Automated Intelligence for the Tactical Army 1980/1990		854530L
5	Low Frequency Shielding		869321L
6	Aerial Very Heavy Lift Concepts for the 1990 Army	Vol I	862287L
		Vol II	506367L
		Vol III	864891L
7	High Intensity Tactical Power Sources for the 1990 Army		865063L
8	Application of Automation to Fire Support Process, LCS-90		8712961
		Vol II	510546L
9	Ground Effect Vehicles		868089L
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10	Mechanized/Automated Stock Handling for the 1990 Field and Theater Armies		867702L
11	Management Information System Requirements for 1990's Combat Service Support		709627
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13	Analytical Techniques for Logistics Management		714367
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15	Navigation and Position Location for the 1990 Army	Vol I	877472L
		Vol II	512555L
16	Mobile/Portable Ports 1990		721011
17	The Man-Machine Interface for 1990 MIS Displays		712998
18	Theater Logistics Control Center - 1990		733348
20	Less Than Lethal Warfare		
21	Theater Transportation Management, 1990 - System Requirements		
22	Joint Transportation-and-Distribution Control Center		
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Report	Prediction and Understanding of Human Behavior		
Report	Fuel Air Explosives (FAE)		

ABSTRACT

The US Army Advanced Materiel Concepts Agency (AMCA) convened an ad hoc working group (AHWG) for 3 days (27-29 April 1971) to survey advanced concepts of strategic transportation. The objective of this study was to identify management problems that might be caused by the exploitation of the fast, high-capacity, versatile transportation envisioned. Seven papers, summarized in appendices of the report, surveyed some of the major technological advances in transportation which may be expected to mature in the next 20 years. With this understanding as a reference, the AHWG was divided into three panels to identify control-center systems requirements related to: (a) advanced technology of transportation; (b) technology related to the materiel shipped and its documentation; and (c) command, control, and communications. Some of the technological concepts discussed were: hypersonic vehicles; nuclear-powered, long-range aircraft; seaplanes; air-cushion and hydrofoil ships; air-cushion vehicles; floating bases; V/STOL aircraft; and dirigibles. The need for electronic labeling and automated documentation of cargo is emphasized. Also, the report points out that the probability of use of hydrogen as a fuel for hypersonic vehicles should stimulate reconsideration of hydrogen as a fuel for ground vehicles in a theater of operations. Finally, the report suggests that dirigibles have been rejected from consideration for the wrong reasons and could, in fact, play an important role in future logistics operations.

PREFACE

This report presents the major contributions of an ad hoc working group (AHWG) comprised of 22 individuals from various military and non-military organizations. The group met for 3 days, 27-29 April 1971. Presentations concerning advanced transportation technology occupied the first day. The second day, and half of the third day, were spent in panel deliberations; and the group presented its findings orally the afternoon of the third day.

The members of the AHWG were encouraged to think creatively and not be inhibited by the normal organizational pressures for conformity and command approval. The ideas contained in this report are, therefore, the ideas of individual participants as influenced by group interactions. These ideas do not have the sanction (nor do they require it) of parent agencies. Even AMCA, while proud of the creative atmosphere it has provided, does not represent this report as an official Agency-approved position. The report is what it purports to be, the faithful reproduction of ideas presented by the conferees.

This AHWG followed a series of four AHWG's concerned with overall logistics management as viewed from the level of the theater commander. Through the medium of these AHWG's, AMCA is seeking technological concepts that will fully exploit the predictable state of the art for the decade 1990-2000 in the fields of sensors for management data, communications, computers, and computer-associated displays. An important application of this technology will be in the sophisticated management-control systems which will inevitably be required to cope with the managerial demands of increased mobility of forces and the great range and lethality of weapons.

AMCA would like to acknowledge the outstanding contributions of each member of the ad hoc working group. We are particularly grateful for the quality of leadership, the dedication, and the breadth of knowledge demonstrated by the three panel chairmen: Mr. Ellsworth Seitz, US Army Computer Systems Command; Dr. Robert Ross, consultant; and Mr. Victor Evans, also a consultant. We would also like to express appreciation to the individuals who presented the outstanding papers of the first day (summarized in the appendices), and to their organizations. Finally, AMCA is grateful to Goodyear Aerospace Corporation and the Logistics Management Institute for contributing the professional services of Mr. Paul Swanson and Mr. Richard Green.

This report was compiled and edited by Mr. Howard J. Vandersluis, AMCA action officer.

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SECTION I

INTRODUCTION

1. The Objective of the Ad Hoc Working Group.

The objective of Ad Hoc Working Group (AHWG) No. 21 was to survey advanced concepts of strategic transportation and major in-theater interfaces in order to identify the management problems that will be imposed by full exploitation of the fast, high-capacity, versatile transportation envisioned.

2. Background Information.

Improvements in transportation technology postulated for the 1990's could significantly reduce the need for in-country stockage while increasing unit readiness and mobility. However, the speed, capacity, and capability anticipated by 1990 dictate the need for major developments in transportation management techniques. Highly mobile combat troops will rely on supplies appearing when needed. Reserve stocks carried by these units will be held to a minimum. Transportation carrying supplies will of necessity often originate outside the theater; however, cargo containers may be transferred between transportation modes (including temporary storage) several times. The location of each cargo carrier with a description of its contents must be tracked in real time so that the carriers can be directed to intersect the courses of the highly mobile units being supported.

3. The Working Group Approach.

The problem was separated into two components: the transportation system of 1990 (this AHWG); and the transportation-and-distribution control center (the next AHWG).

A scenario was provided which, while not reflecting a real-life situation, comprises conditions which together form one of the worst cases for command and control. Visualize a commander in (1) a country in the interior of a continental land mass or (2) in a country on the coastline of a land mass. There are no satisfactory lines of communication existing in the country prior to entry of US troops. The enemy is well-trained, dedicated, numerically equal or superior to the US force, and capable of operating anywhere in the theater without exposing himself to decisive combat. His few sophisticated weapons systems give him the capability, with minimum logistical stress, of disrupting our great potential for mobile operations. The total US force consists of five Army divisions, Air Force tactical units and

carriers, and Naval units, supported by a broad mix of equipment and conventional weapons. The country is separated by an ocean from the US and is 6,000 to 10,000 miles from bases in the US. The environment varies from tropical rain forest to a high mountain range.

The AHWG divided its work into five areas as developed by three panels within the group. These areas were:

a. The planning necessary in order to develop by 1990 the capability to perform the operation depicted by the scenario. (Section II)

b. The technology that could be made available by 1990. (Section II)

c. The concepts of future transportation technology that could provide the required range, capacity, speed, and flexibility for movement of troops, equipment, and supplies. (Section III)

d. Systems requirements related to command and control, and corresponding aspects of communications and electronics. (Section IV)

e. The Commodity Oriented Digital Input Label System (CODILS) which proposes an electronic label and associated automated documentation system for identifying and controlling unitized supplies in transit from any point in CONUS to an overseas consignee. (Section V)

SECTION II

PLANNING CONSIDERATIONS FOR THE 1990's

1. The Expanded Scenario.

Technological improvements throughout the transportation system will make possible greater responsiveness to user requirements in the 1990's. However, to enjoy the benefits, the users and operators of 1990 transportation must undertake certain activities in the 1970's. As a starting point, the military services and other DOD components could profit from structuring a scenario against which theoretical but realistic planning and research may be set in motion. The brief scenario provided the AHWG (and summarized in section I) is considered appropriate in this respect. The AHWG's exercise of the scenario began with:

> The US deploys a task force (five Army divisions, tactical aircraft, cargo aircraft, Naval units, equipment, and a 3-day supply level). The task force is to be closed in the theater in C+10 days (10 days from the time deployment commences). Resupply starts moving from CONUS at C+48. Initial resupply (first 15 days after force closure in the theater) will be by aircraft. Later resupply would include slower modes.

To this scenario the following additional provisions apply, based on a general appraisal of attainability of current scientific and technological concepts and objectives:*

- CONUS computer capability will be made available to furnish necessary computing and data-base requirements in support of the operation, thus minimizing the support requirements in-theater. All services will have equal access to the data base.

- Activation of the contingency (operation) plan will immediately institute precedence procedures that will allocate primary and secondary communication channels necessary for the complete operation.

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* The provisions and planning considerations contained in this section were adapted from applicable and realizable "assumptions" contained in the report of AHWG No. 18. These assumptions were prepared by Mr. Ellsworth Seitz, US Army Computer Systems Command, a panel chairman for both AHWG's.

- Adequate (though carefully budgeted and controlled) funds will be allocated to support the implementation of the total contingency plan.

- In the time frame (1990's), the concept of the CONUS Theater Oriented Depot Complex (TODC) or equivalent will be fully implemented, making overseas inventory control centers (ICC's) and depots unnecessary (though "surge" stockages will still exist).

- Most major programing requirements will be satisfied in CONUS.

- The equipment configurations for tactical and logistical management-control systems will be compatible.

- All services of DOD will have trained commanders and staff officers in the understanding and use of the capabilities depicted by this report.

2. Planning Requirements.

Planning to meet the US objectives within the parameters of the above expanded scenario must be started not later than 1975. This planning must include:

- Total concept planning of force deployment, employment, and resupply operations. (Redeployments must be planned to provide flexibility in response to changing operational situations.)

- Training of operating and staff personnel.

- Means of achieving productivity of research and development where necessary to bring vital equipment programs to fruition.

- Initiation and development of organizational doctrine to effect changes necessary to implement plans.

- Initiation and development of procedural documentation to implement plans.

- The adoption of uniform and standardized provisions for networking logistics computers of all services involved.

- Development and configuration of computer and communication architectures to achieve maximum desirable automation of data collection, analysis, and display.

3. <u>Technology Attainable by 1990</u>.

- Total prepackaged Theater Logistics Management and Information Centers (TLMIC) can be developed and available for deployment.

- Adaptive and/or heuristic computer processing can be available to assist managers in their analysis and evaluation of dynamic conditions.

- Computer models adaptable to each contingency plan can be developed to test changes and modifications, and to accommodate to changing conditions in-country or changes in strategic plans.

- Electronic microminiaturization techniques can be fully optimized and applied, thereby, reducing weight and bulk and, thus, enhancing transportability.

- A family of natural-language, functionally-oriented computer languages and an associated family of compilers can be developed which will simplify programing, improve the efficiency of operating programs, and facilitate a common understanding by all staff and functional personnel.

- Standard formats of data displays can be developed to facilitate a common understanding by all staff and functional personnel.

- During the early stages of an operation, the major in-country computers can be designed to act principally as interface computers between CONUS and the country. Their function would be to exploit fully the CONUS capability. In-country capabilities may be expanded later if the operation is prolonged.

- In-country computerized terminals can use microprograming and virtual memories to reduce memory requirements and substitute optical for magnetic memories to reduce vulnerability.

- The CONUS computers interfacing with the theater can employ array processing and associative memories as well as multiprocessing and time sharing to improve their response to theater demands.

- As backup to the communications-electronics system, data storage devices may be transferred from point

to point by messengers to reduce the impact of communications degradation.

- Voice input can be developed, at least to a limited extent as for operator authentication and for a standard set of commands.

SECTION III

FUTURE TRANSPORTATION TECHNOLOGY

1. Introduction.

Although it is not possible now to predict technological breakthroughs which might be expected regarding transportation systems in the 1990's, it is quite feasible to extrapolate current knowledge. We can count on two very important advances: an increase in speed of transport and an increase in payload. These can be accomplished with the use of more power and bigger vehicles. An increase in range, however, may not be achievable unless a proved need exists and technology is driven to meet it. This is also true for such features as reduction in landing field requirements, improving offloading times, etc. Each can be provided if we are willing to pay a penalty to achieve special performance.

The panel examined various transportation modes and postulated their performance gains in a total transportation system. (Only prime transportation modes were considered. Special purpose techniques such as ballistic delivery were not included.) Where vehicle performance was hampering the total operation of the system, it was modified; but, only to the extent that modification might be possible in the 1990 time period. When it was considered impractical to stretch the capabilities of any particular mode of transportation any further, a new mode was brought into the system.

In addition to the major vehicles described, this brief study found two areas which warrant additional attention since they could substantially improve the entire system performance. These were: (a) hydrogen as a fuel, and (b) heavy-lift airships.

The technology portion of this study could be performed without interface with the management and communication functions because it was assumed that the performance parameters of each vehicle would be fed into a system which would react automatically. This not only is readily accomplished but necessary so that changes in vehicle performance do not require changes in either the management, control, or documentation. Whenever vehicles with increased speeds or payloads are added to the system, for instance, the system would automatically call for fewer of them to perform the same task.

2. Overview.

If greatly increased range is identified as an important objective, it is anticipated that nuclear-powered vehicles will be the solution. These will be aircraft or high-speed surface vessels.

For the shorter haul operations, VTOL aircraft and air-cushion vehicles with wheels would be utilized. Although designed as special-mission vehicles, each could serve to complement the other. These appear to be the only new vehicles that may be required by an advanced, containerized, transportation system; and they primarily support the movement program, aided, as necessary, by conventional equipment.

If for some reason the nuclear capability cannot be implemented, the long-range vehicles would be large, air-cushion ships and jumbo-jet-type aircraft, supported by portable off-shore bases. The entire concept, however, is based on fast movement of all personnel and equipment, and self-sustaining capability. A minimum number of vehicle types is postulated; but the vehicles would have great versatility.

3. Port Clearance for Land-Based Transportation.

Bases would be semi-permanent in nature with air strips under 10,000 feet long, capable of operating within 30 days, and handling the following incoming traffic:

- Long-haul, 200-ton capacity, subsonic, nuclear-powered aircraft operating directly from CONUS.
- Long-haul, 200-ton capacity aircraft operating from CONUS (with refueling bases) or from intermediate bases.
- VTOL type, 50-ton capacity aircraft operating from forward bases.

A major portion of the incoming cargo will be shipped in containers with capacities of 25 to 50 tons. Oversized and overweight cargo to be handled will include armored vehicles, trucks, helicopters, ground support equipment, etc.

Movement from a port may be by VTOL aircraft[1] or special over-the-land, air-cushion vehicles, as well as conventional, wheeled vehicles. Most cargo to be carried by these vehicles will be containerized. Minimal breakdown and storage of containers (with the exception of fuel[2]) will be made at this port facility. Mobile equipment off-loaded here will be dispersed under its own power and will require nothing more than a make-ready and fueling area.

[1]See Aerial Very Heavy Lift Concepts for the 1990 Army, Volumes I, II, and III, November 1969, report of AMCA AHWG No. 6. (AD 862287L, 506367L, 364891L).

[2]POL distribution is discussed in paragraph 5, this section.

Containers will be transferred directly from the incoming aircraft to the outgoing aircraft or air-cushion (or conventional) vehicles. To accomplish this, the incoming aircraft will be fitted with roller-conveyor type handling devices on which the containers will be moved to the outgoing vehicles (figure III-1). If winches or movers are required, these can be on the outgoing vehicles. Minimization of special ground handling equipment is a prime consideration.

Having adequate numbers of the transportation vehicles on hand when the incoming aircraft arrive is the key to the operation, if temporary storage is to be avoided. On-call VTOL capability will be a prime requisite of this system's success. The overall goal of this system is the unloading, servicing, and loading of incoming aircraft on a 30-minute turnaround schedule.

4. Port Clearance for Seaborne Transportation.

Improved sealift technology resulting in high-speed (50 to 100 knots), 1,000-10,000 long-ton-payload vessels (4,000 to 40,000-ton gross weight) will require better methods of port clearance in the 1990's.* It is anticipated that surface vessels of this class will provide approximately 80 percent of the follow-on supplies required by the initial tactical forces in a theater.

It is assumed that the majority of cargos will be modularized and that through-put delivery direct to user will be the method of onward distribution. Port clearance functions center around two main areas:

- Loading and offloading transport.
- Forwarding cargo to user and processing retrograde cargo.

a. Loading and Offloading Vessels.

Since it is anticipated that the port environment will be primitive, vessels will be required to be equipped for loading and unloading. This equipment will include on-board conveyor systems or elevators. Port or beach storage will not be utilized since all cargos will be directly and immediately forwarded to users upon discharge and directly loaded if retrograde. Retrograde containers and other cargo must be acceptable for loading from the incoming transport to the ships.

*See Mobile/Portable Ports 1990, March 1971, report of AMCA AHWG No. 16 (AD 721011) and Mechanized/Automated Stock Handling in the 1990 Field and Theater Armies, April 1970, report of AMCA AHWG No. 10 (AD 867702L)

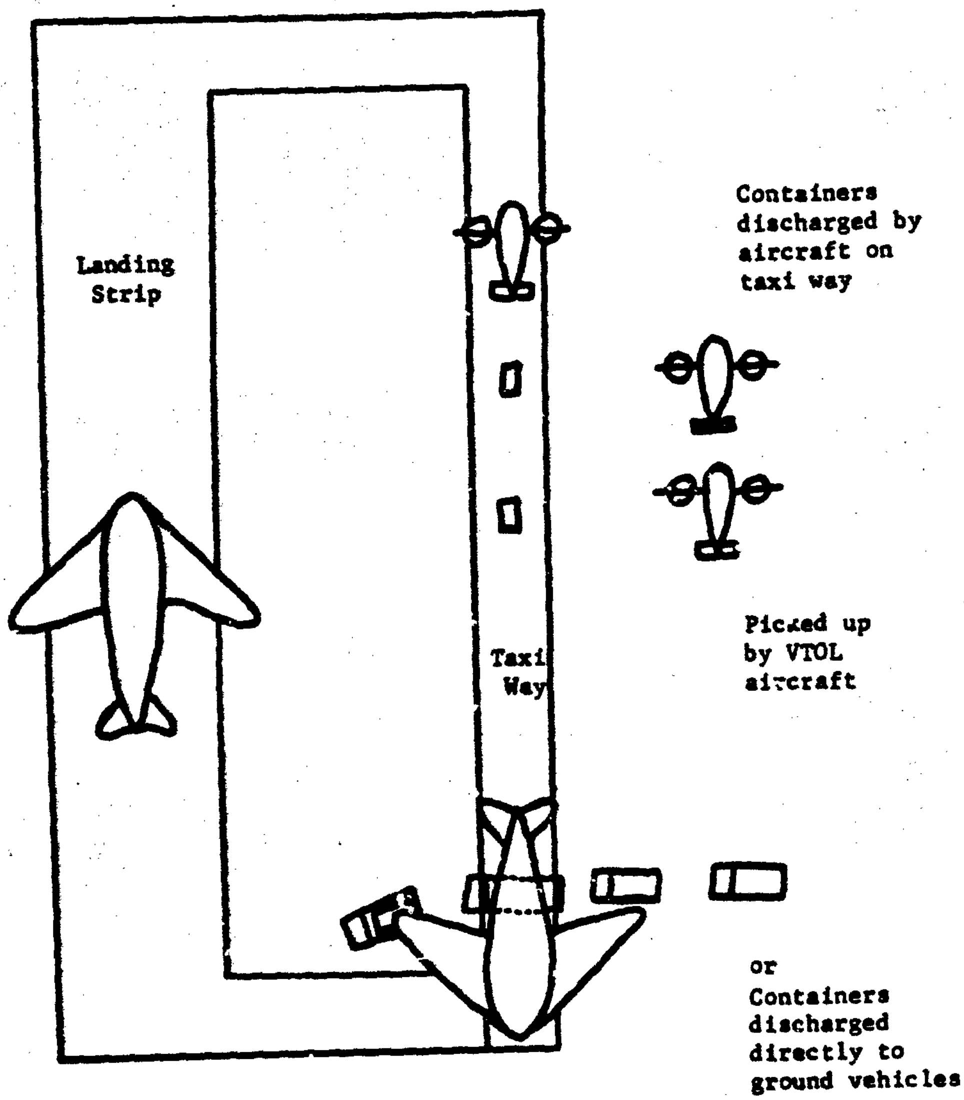

Figure III-1. Direct transfer of containers from incoming aircraft to outgoing intra-theater transportation.

b. Forwarding Mode.

Considering the various modes available, it was decided that a VTOL-type craft would provide the best capability for port clearance direct to the user, in view of the trade offs necessary in requirements for hovering, speed, and range. Use of VTOL aircraft would facilitate off-shore discharge of vessels.

c. The Interface.

The combination of high-speed surface vessels and VTOL craft should result in the optimum utilization of both modes with a resulting improvement in productivity of the logistics system.

5. Logistics Support for Transportation.

Under this scheme, (figure III-2), requirements for logistics in support of the transportation system would be minimal for everything except the fuel and maintenance required to sustain in-theater transportation:

- There would be no requirement for intermediate support between the seaport (SPOD) and the forward aerial port of debarkation (APOD), as all commodities would move by air without parallel highway transportation nets.

- Materials-handling equipment and support troops would be concentrated at two locations only, the seaport and the aerial port.

- With use of nuclear fuel in the strategic transportation, there would be no in-theater requirement to furnish them with POL.

- The dependence on component replacement and limited number of prime mover types should reduce the required in-theater maintenance.

Fuel requirements will be extremely heavy throughout the theater. These requirements will be met by delivering fuel in standard containers intermixed with other cargo throughout the theater. Since transportation will be extremely responsive, there will be no need for large POL dumps or storage facilities. Containerization of fuel eliminates many of the requirements for special purpose semi-mobile, fuel-handling facilities. Fuel may also be delivered in large capacity haul-away tank trailers for mobility within the theater.

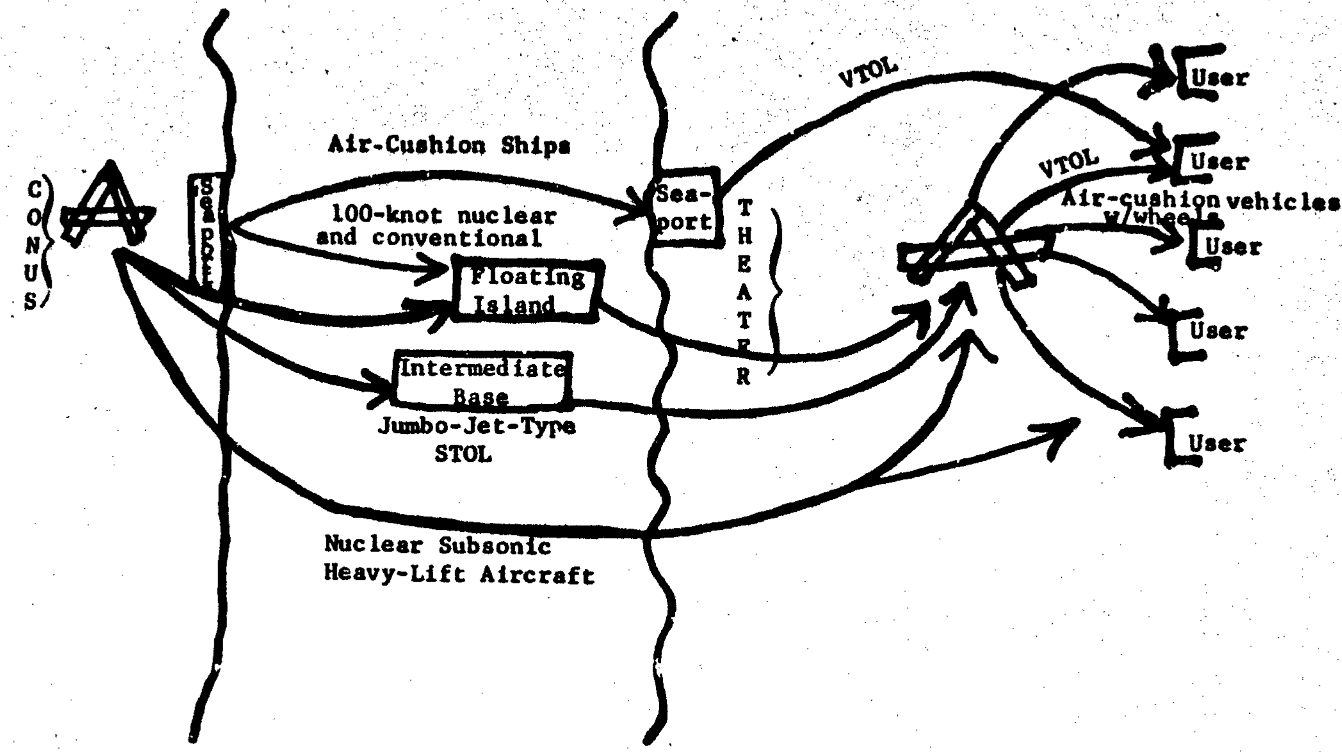

Figure III-2. Scheme of transportation system.

6. The Port Facility.

The port (SPOD) facility would be developed largely from prefabricated components moved in as soon as the shore is secured. While military craft would be offloaded directly to delivery vehicles, as described in the previous paragraph, the facility would, as soon as possible, provide offloading equipment for commercial ships, and VTOL pickup points to move containerized cargo forward. The container marshaling yards would be small because sufficient VTOL capability would be present to move containers out immediately upon offloading from the commercial ships. In-yard movement of containers would be accomplished by second-line air vehicles such as heavy-lift helicopters or airships.

The marshaling yard for containers, the ship-unloading facility, and a small VTOL maintenance and evacuation element would be the port's only facilities. It would occupy a physical area much smaller than that presently occupied by military ports as it would function only as a transfer point and contain minimal break-bulk facilities. The maintenance element located there would consist of minimal component change, inspection, evacuation, and recovery elements for VTOL.

7. The Aerial Port of Debarkation (APOD).

The APOD would consist of a semi-improved runway under 10,000 feet, VTOL and air-cushion vehicle maintenace units, a marshaling yard with crew, and one or more air terminals with operating and support personnel. Although the base would have some materials-handling equipment, probably augmented by heavy-lift helicopters, the primary emphasis would be on mode-to-mode direct transfer. The marshaling yard and break-bulk facility included would be used only on an exception basis. Most supplies would be addressed directly to the using unit. An additional function of this facility would be the preparation of recoverables for return shipment. The maintenance unit, which would perform only major-component replacement and evacuation, would maintain only minimal stocks of repair parts and require little in the way of fixed facilities.

8. Portable Offshore Base.

Though not "transportation," strickly speaking, portable ports were considered because such a concept seems essential if advanced transportation capabilities are to be exploited. Offshore bases can be used to receive incoming aircraft and/or surface ships and to dispatch outgoing short-haul aircraft, VTOL, and air-cushion vehicles. A desired length of this base would be 3,000 to 5,000 feet and have adequate area for all loading and unloading activities. If the shoreline is denied, this base could be used for troop dispersal as well. This base must be defensible, portable, and be erectable in relatively short periods of

time. Several concepts have been proposed for this type of base. Some of these are described in the paper "Floating Islands and Bare Bases," by Paul Swanson, appendix H.

9. Theater Maintenance.

Theater maintenance will be limited, in general, to component replacement. This service will be provided by a direct support unit using heliborne mobile maintenance teams. When a team cannot make an item serviceable by component exchange, evacuation will be initiated. At the first node of the evacuation chain, a determination will be made to either continue the evacuation or to dispose of the item. This decision will be based on: critical skills and material resources required to accomplish repair, procurement cost, replenishment-from-stock costs, and item combat essentiality.

If a decision is made that the item is repairable, retrograde movement will be accomplished through the surface transportation mode (if not denied in highly dispersed deployment), except for selected items that routinely move by air. Repair and overhaul will be accomplished either in CONUS or at some other base outside the theater.

10. Hydrogen as a Fuel.

It is the recommendation of the working group that a feasibility study be conducted of the use of hydrogen fuel for all transport modes operating in the forward area. The transportation system assumed relies on highly mobility vehicles, primarily aircraft. The price of high mobility is high fuel consumption. Perhaps, half of the payload brought into the forward area will be fuel required to further distribute the other half. The attractiveness of hydrogen in these circumstances lies in the fact that it could be produced in the forward area. One of the first items to be delivered to the forward air base would be a nuclear-powered electrolysis plant. (This concept depends, of course, on the availability of water.)

The use of hydrogen has been studied for hypersonic, long-range, transport aircraft. The problems uncovered by these studies will be encountered in the short-range application, too; but tradeoff studies may well demonstrate substantial gains in transportation delivery capability. Many difficult problems must be explored. The low density of hydrogen requires that it be stored in liquid form, but even then the fuel volume requirements impose unusual demands on vehicle configuration. Fuel loss through boil-off must be traded against the amount of fuel tank insulation. Since fuel production is a continuous process and consumption is discrete, provision must be made for temporary storage of liquid hydrogen in the producing area, with accompanying insulation problems. The actual fueling and transfer of liquid hydrogen requires special consideration also, from safety and security

standpoints. The feasibility study will of necessity include the development of suitable engines, probably Brayton cycle, for all vehicles, including wheeled and air-cushion ground transport. (Hydrogen fuel cells and electric motors should also be considered as an alternative.)

The impact of the use of hydrogen fuel may extend to other areas. Since the fuel would already be available at the forward air bases, hypersonic aircraft may well be the most productive long-haul configurations. The development of long-haul hypersonic aircraft for military purposes would have strong impact on civilian air transport as well. A feasibility study of the use of hydrogen fuel in the 1990 time frame is now appropriate; possible benefits may be wide-ranging.

11. Lighter-Than-Air, Vertical-Takeoff-and-Landing Airships.

One area that appeared to warrant further investigation is the upgrading of lighter-than-air technology with the advances that have been made in aerodynamics, propulsion, control, and materials development during the last 30 to 40 years. A large vertical-takeoff-and-landing (VTOL) nuclear powered airship with approximately a 1,000,000-pound payload could be built and made operational for handling the transportation of all personnel and equipment from CONUS to the general area of operation. It could be designed to travel at 150 to 200 miles per hour and would have no range limitations. The landing field needed would be minimal, requiring a cleared area slightly larger than the plan form of the vehicle itself. As to vulnerability, major damage would be required to knock it out of the air, since the helium within the envelop simply displaces the air that would normally be there and, therefore, is at the same pressure as the surrounding atmosphere. The helium would escape very slowly even through quite large tears in the envelop. Furthermore, the airship, moving fast at very low altitudes, would be difficult to hit. (Nevertheless, there is no doubt but that the huge size of the airship would make it an attractive target.)

One of the major drawbacks for the use of nuclear power in aircraft is the safety problems. In the event of an airplane crash, it might not be possible to contain the radioactive debris and this would present a danger to the entire area of the accident. In the case of the lighter-than-air vehicle, however, the chance of a crash is reduced because much of the lift is provided by the inert helium gas. In addition, the vehicle is so large that it would be practically impossible to create a situation that would decelerate the powerplant at a rate that would break its shielding. The energy would be absorbed in the collapse of the surrounding structure instead.

The need for an almost infinite range makes nuclear power attractive. The ability to go by air eliminates many of the terrain difficulties normally encountered by ships and trucks, and the million-pound payload

with the large-volume capability would result in the ability to carry almost any payload by this mode of transportation. Furthermore, since the power required to operate this VTOL vehicle is only a fraction of that needed by a helicopter to perform the same lift function, the economy of operation is very attractive. It would not quite meet ship rates, but could be competitive with truck operations.

A fallout from the development of this large transporter would be the possible commercial use of such vehicles. The availability and safety of the non-flammable helium, the quiet non-polluting propulsion, and the economy of these vehicles would be most attractive to the general public. Once these are in the commercial inventory, they could be considered as an emergency back-up for military use if the situation ever became so critical as to require it.

12. Summary of Future Transportation Technology.

The major characteristics of future transportation technology as postulated by the AHWG are:

Inter-Theater

Air

- Subsonic
  - Nuclear
  - 200-short-ton payload
  - Less than 5,000-foot runway
  - 30-minute turn-around time
  - Range limited only by crew endurance

Surface

- Air-Cushion Ships
  - 50 to 100 knots
  - Nuclear powered and non-nuclear
  - 1,000 to 10,000 long-ton payload

Intra-Theater

Air

- Jumbo-Jet-Type Aircraft
  - Chemical fuel
  - 200-short-ton payload
  - 3,000-foot - 5,000-foot runway
  - 2,000-mile range
- Vertical Takeoff and Landing
  - Chemical fuel
  - 300-400 knots
  - 50-short-ton payload
  - 200-mile - 500-mile range

Surface

- Air-Cushion Vehicles
  - 50-short-ton payload
  - 100-mile range

Feasibility Studies Recommended

- Hydrogen as Fuel
- Lighter-Than-Air, Vertical-Takeoff-and-Landing Airships
  - 150-200 knots
  - Nuclear
  - 500-short-ton payload.

13. Seaplanes.

Although seaplanes have many attractive characteristics when water bases are available, they were not included in this report as it is expected that current developments in air-cushion landing gear for land planes will result in a versatility that encompasses the water capability. However, the paper read by Mr. Richard Murphy (appendix D) summarizes the state of the art for seaplanes.

14. Conventional Sealift Fleet.*

An important aspect of future transportation has not been covered. This is the conventional sealift fleet which could be in being in the 1990's. Even these seemingly modest advances are not going to be available by 1990 unless Congress takes action to support the Maritime Administration's program, however.

The US-Flag Sealift Fleet will drop from a total of 500 vessels in 1970 to 270 in 1975:

	1970	1975
Freighters	367	162
Container Ships	88	68
Partial Container	22	22
Combination	19	14
Barge Ships	1	1
RO/RO	3	3
TOTALS	500	270

(The diminishing role of the freighter is not surprising but the reduction in container ships is.)

*The balance of this section was provided as a commentary, and warning against excessive optimism, by Mr. Elwood Hurford, US Army CBC Personnel and Logistics Systems Group.

The bread-and-butter strategic transport capability for the 1990's will remain the sealift fleet. It is unlikely that Congress will subsidize mass development of the type of aircraft which would be needed to deploy a joint task force including five Army divisions in 10 days in 1990. The Maritime Administration's program includes Multipurpose Ships (MPS). These ships would be 650 feet long, 100 feet at the beam, cruise at 21.6 knots, and have a 13,000-mile cruising radius. They would each be capable of transporting 1,000 containers (8'x8'x20'), have approximately 150,000 square feet of vehicle storage space, and have two organic CH54B's (or later generation heavy-lift helicopters) on board. These MPS's would fill the void which resulted with elimination of the FDL (Fast Deployment Logistic) concept.

To progress toward a reasonable strategic deployment capability for the 1990's, we must continue to hammer at attainable goals. If developments proceed as they now are, we will not be able to support over-the-shore operations in the 1990's. Recognition is needed of the requirement for an improved surface fleet. There are a multitude of challenges in the materiel area: antisubmarine devices, antiaircraft and antimissile protection, unloading systems, cargo accounting systems, and selective discharging capabilities. By the 1990's, we may have to depend upon forward floating-depot concepts as well as quick reacting air fleets.

SECTION IV

COMMUNICATIONS, AND COMMAND AND CONTROL

1. Introduction.

The managers of transportation are not constrained by vehicle types except in terms of speed and, consequently, by compression of time. This panel, therefore, focused on the problem of communications for a dynamic and viable system.

2. Functions of Transportation.

Figure IV-1 lists the shipping functions performed in the transportation system. The panel did not believe that this basic concept differs materially from that which should take place today. However, in the future the entire system will be more flexible than at present. All functions may have to be performed at any and all nodes of the system. For example, a break-bulk point may have to perform the consolidation function.

CONUS

- First-Loading / Documentation
- Consolidation — Physical / Documentation
- Movement
- Port of Embarkation (Air or Sea)
- Documentation Transfer to Theater

IN-TRANSIT

- Diversions
- Responses to Unanticipated Happenings

THEATER

- Receipt of Documentation
- Port of Debarkation (Air or Sea)
- Documentation as Required
- Movement
- Break Bulk/Depot*/User

Figure IV-1. Primary shipping functions performed in the transportation system.

The management of transportation includes other functions than those for shipping materiel. These functions involve the management of the transportation resources and are, basically:

*Surge stocks, not conventional depot.

- The "care and feeding" of individual vehicles including manning, training of personnel, and maintenance of the vehicles.

- The allocation of vehicles to move the required materiel, including in-transit control.

- Responding to the changing tactical situation.

While these functions are not directly concerned with shipments, they are activated by the needs of moving materiel from one point to another.

3. Information Flow.

Figure IV-2 represents the flow of information for both the supply and the transportation activities. The upper segment represents the physical flow -- in a box, container, ship, or aircraft. Arriving in the theater, it breaks down from the ship or the aircraft back to the container, the box, and the individual item. Note that the transportation data flow is progressive in aggregation and distribution, while the supply data flow is continuous since it is need-oriented. Stated another way, transportation managers are interested in the largest aggregation whereas supply managers are always interested in the individual items shipped regardless of consolidation or means of conveyance. To this end, the transportation data concerning boxes is retained only as long as the box is the largest item being transported. When boxes are put into containers, the box information is dropped.

Note also that the data bank serves two masters. It must be capable of responding to both without impediment to either. At the present time, it is usually a simple matter to get information on the location, destination, and time of arrival of the specified ship, for example; but it is difficult to get current information on a specific item or requisition in transit.

4. Problem Areas.

The problem areas that the panel felt are germane to the 1990 system are:

- The decision-making time cycle will be highly compressed.

- Each control point must be able to assume and perform additional primary functions; therefore, the system must be highly flexible.

- System electronics, as well as electronics devices in storage and in-transit, are highly vulnerable to nuclear electromagnetic radiation.

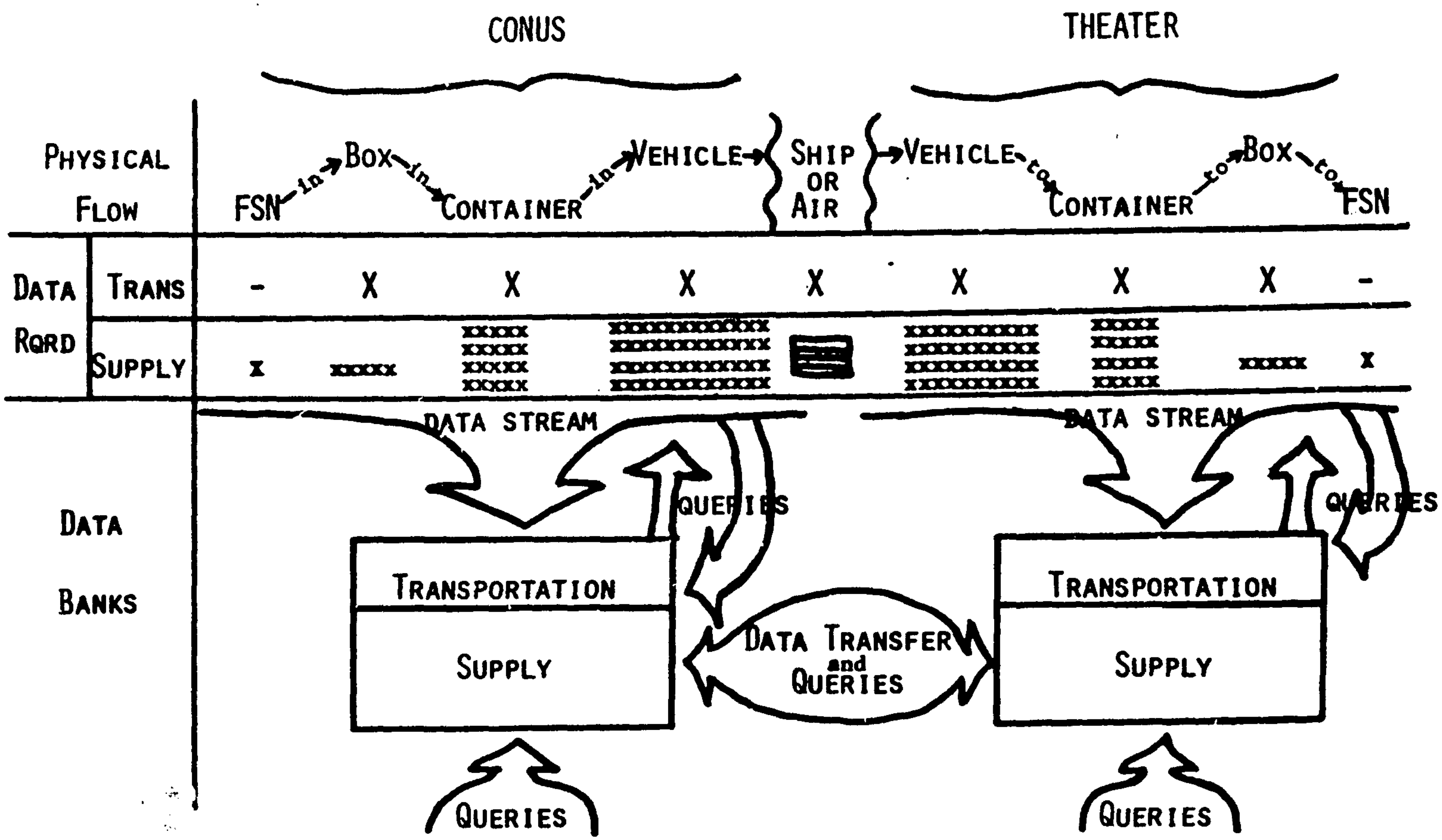

Figure IV-2. The flow of data for supply and transportation.

- Much higher visibility of data and information will be required.

- Much greater integration of functions will be required; i.e., command, maintenance, supply, transportation, facilities.

A very significant fact here is that we have a true dichotomy in which time is both our ally and our enemy. While high-speed transportation improves our response to troop needs, it also decreases the time available to make decisions. Time will not be available for a study to determine whether to go directly to a consignee with a shipment, divert it from point A to point B, or send it to a break-bulk point.

5. Approaches.

The panel listed the following approaches as essential to the success to any system developed:

- Manned backup (see paragraph 6).

- Intensified personnel training to operate sophisticated communications, command, and control equipment, and to take over in the event of degradation of the equipment.

- Internal contingency plans to facilitate rapid response to changing conditions, including equipment degradation (or even catastrophic failure).

- Standard operating procedures for management information systems applicable to the total logistics function.

- Highly motivated training and on-the-job guidance for traffic managers.

It is important to realize that some of the above approaches may well become significant problems in and of themselves and may require considerable effort in research and development.

6. The Human Element.

The panel felt that it is particularly important to avoid neglect of the human element in transportation management. The machinery of transportation is so impressive that it is easy to forget that an efficient transportation system depends on human operators, human planning (especially to link different modes of transportation at interfaces), and human interpretation of the vast quantities of data continuously arriving at control nodes in the system.

Management must not be abrogated by machines. Even with the advanced sensors, communications, computers, and information displays, which can be postulated for the 1990's, managers must recognize that technology provides tools to individual managers and not management itself. Managers must be prepared to perform the functions of management whether the technological tools are fully operational, degraded, or not functioning at all. The tools must be made responsive to the masters, not the masters to the tools.

SECTION V

MATERIEL-DISTRIBUTION MANAGEMENT

1. A Conceptual Electronic Labeling System.

To achieve "inventory in motion," a capability for real-time visibility of materiel enroute and in storage, as well as transportation availability, must be developed worldwide. The CODILS concept set forth in AMCA Report-71-008, Commodity Oriented Digital Input Label System (CODILS), April 1971, by CPT Edgar Crooks, provides this capability. The abstract of the report states:

> "The Commodity Oriented Digital Input Label System (CODILS) concept proposed in this report uses an automated labeling system for controlling and identifying unitized supplies in transit from any CONUS source to an overseas consignee and for controlling retrograde shipments. Further, the automated labeling system can be used as part of a larger management system to control, locate, divert, and otherwise manage cargo and/or vehicles in transit and within depots or terminals. The report discusses how, for the present at least, non-optical techniques appear to offer a better solution to the problem than optical techniques. The system electronically interrogates a label attached to a unitized or palletized load and enters the label number, together with certain shipment status information, into a computer. Subsequent update information is passed to the computer by electronic interrogators located at the various transportation nodes throughout the logistics pipeline without any requirement for hard copy documentation, including receipt and shipping tallies. System and hardware concepts for the 1990's are projected. Cost estimates for the implementation and operation of the CODILS concept have not yet been made. Finally, the report discusses spin-off applications in other areas."

2. Advantage of Electronic Labeling.

Specifically, advantages of automatic identification over present manual methods are:

- Substantial reduction in error rate. Inaccuracies introduced by human error can cause disruption to the orderly flow of military supplies.

- Improved capacity for rapid response to supply requirements. This improvement affects not only the large numbers of containers in transit, but also those stockpiled containers having reserve supplies.

- Reduced overall manpower requirements.

- Immediate readout if required.

- Capability of reading at high vehicle speeds, day or night, under unfavorable weather conditions.

- Improved control of critical supplies. These shipments may be identified and located at the instant the container passes a reader.

To implement CODILS, extensive use of electronically interconnected computers is envisioned. This makes possible such long-sought-after goals as worldwide asset visibility and realistically responsive inventory in motion. However, it should be emphasized that the advantages of automatic identification using the CODILS tag and scanning devices would be of value even if used only within individual depots, ports, or transship points, with data passed from installation to installation by conventional means.

3. Impact of CODILS on the Logistics System.

The introduction of such a capability would have a major impact on logistics by reducing stockage levels, order-and-ship times, and the almost overwhelming cost (and error rate) of cargo documentation. A few specifics are:

- CODILS makes unnecessary the inquiry and reply formats of MILSTRIP. These formats equal about 75 percent of the 26 MILSTRIP formats.

- Savings in communications, however, will be balanced by requisitioners' inquiries to the CONUS central transportation computer.

- With a "push" supply system and automatic usage reporting through CODILS, much of the current requisitioning load could be eliminated.

Since the data on most cargo documentation is contained in one or more computers in CONUS and overseas at the present time, total requirements for DOD computer capacity would, in all likelihood, not be increased appreciably in order to support a CODILS-type system.

Since the documentation cost for DOD cargo is not readily available, the experience of American commercial exporters will be discussed. In 1969 American exporters spent, for documentation alone, approximately 13 billion dollars, according to the International Trade Documentation Council. Approximately 80 percent or more of this could be eliminated by a commercially applied CODILS system, leaving only the documents needed for legal and tax purposes. Applied to a DOD documentation system, cost reductions provided by CODILS could be impressive.*

4. Data Protection.

CODILS equipment specifications are outlined in the AMCA report on CODILS; however, a specific area which the equipment designs should also stress is data protection. Protection already planned for the label and memory chips is:

- The memory circuitry within the label should not be readily susceptible to memory scrambling under nuclear radiation environment. Its vulnerability to an electromagnetic pulse must be determined.
- It should not be possible to alter the coded number stored in the electronic label after manufacture.
- The label in its final production model should be impervious to weather and operate reliably in the temperature range of -60°F to +200°F.

5. Data Security.

- The labels attached to or accompanying cargo must remain passive except during interrogation. Continuous RF emission is unacceptable.
- Effort must be expended to protect against triggering or jamming of the electronic label by a hostile force.

6. Data Output Requirements.

- Electronic label output shall be in digital form, or be capable of conversion to digital form by the interrogator/receiver.

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*Study of DOD International Personal Property Moving and Storage Program, LMI, April 1970, provides an estimate that DOD spent approximately $700,000,000 to move household goods in 1969, half of which was Government costs to produce documentation and other paperwork.

- The label shall be capable of outputting at least 14 numerical digits or integers to the interrogator. Even under conditions of general label use worldwide, it will not be necessary to repeat the sequence any more often than every 10 to 15 years.

7. Research Requirements for Multiple Tag Interrogation.

Research on a cheap method to allow simultaneous readings of multiple electronic tags in bin storage and/or storage areas is required. At present, this can be done only through an expensive buffering system or by use of tags manufactured so that each series of tags falls into a different frequency spectrum. This last system works only if no more than one tag in each frequency is present during mass interrogation.

APPENDIX A

AD HOC WORKING GROUP NO. 21

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APPENDIX B

HIGH PERFORMANCE SHIPS
(HYDROFOIL AND AIR-CUSHION CRAFT/SHIPS)

by

Dr. Basil V. Nakonechny
Naval Ship Research and Development Center

SUMMARY

1. Introduction.

My comments concern two kinds of craft, dynamic-lift vehicles and aerostatic-lift vehicles. Specifically, the status of current hydrofoil and air-cushion technology is briefly discussed here.

The major reason for the employment of hydrofoil and/or air-cushion craft/ships is the desire to lift the hull from the water and thus circumvent the constraints on high speed due to wavemaking and frictional resistance, and at the same time achieve easier, smoother behavior in waves. The hull of a hydrofoil ship is supported above the water surface when underway by the dynamic lift of underwater wings or "hydrofoils." In case of an air-cushion craft, the main hull or structure is supported above the water (or ground) surface by an air cushion. The power used to generate aerostatic lift is called the cushion power and the power used to generate thrust is called the propulsion power.

2. Hydrofoil Craft/Ships.

The first "flight" of a craft using hydrofoil principle took place over 70 years ago. Subsequent development of this type of craft, during almost the entire first half of the twentieth century, was rather sporadic with very limited financial support. During World War II the German Navy built a few experimental hydrofoil boats for military purposes. Since that time much more systematic development has taken place. European effort led to the commercial Supramar craft, of which about 100 of different sizes are now operating in many countries. These craft are equipped with surface-piercing type foil systems.*

*Hydrofoil craft/ships with a surface-piercing foil system derive their lift-force, required to lift the hull clear of the water, from the lifting surfaces which themselves penetrate the air-water interface. Such systems are self stabilized because if the foil is displaced

In the Soviet Union, hydrofoil craft were not developed until after the war when the Soviets took over the Eastern part of Germany and captured the Sachsenberg shipyard at Dessau-Rosslau. Over the past decade the Soviets have been involved in a hydrofoil craft building program on a large scale; there are hundreds of operating craft of various types on the inland waterways. Most of the Soviet craft, those employed on inland waterways and those used for coastal work, are equipped with a shallow, fully-submerged type foil system with additional lifting foils/surfaces for purposes of enhancing the transverse stability of the craft during the takeoff process.[1]

Most of the hydrofoil craft which have been built in this country have been experimental in nature. In the period from 1947 to 1960 the Office of Naval Research, with the support of Bureau of Ships, sponsored a number of research and development projects directed toward the establishment of fundamental criteria for the design of hydrofoil craft. One of the first small hydrofoil craft resulting from this activity was the SEA LEGS. Through the joint efforts of Gibbs & Cox and the MIT Flight Control Laboratory, it provided the first real demonstration of the feasibility and advantages of a fully-submerged, automatically controlled foil system.[2]

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downward from its equilibrium position, the increased submerged area of the foil generates additional lift which acts to raise the foil to its original position. Likewise if the foil is displaced upward, the reduced lift causes the foil to be lowered again. This stabilization is sufficient to provide a comfortable ride in moderate sea-states without an active control system.

[1]Hydrofoil craft/ships with a fully-submerged foil system derive their entire lift-force, required for lifting the hull out of the water, from the lifting surfaces which are placed completely below the air-water interface by means of strut supports. The foil system used in the Soviet craft is based on the effect of the free surface on the lift-curve slope of a completely but shallowly submerged foil. At depths of immersion less than one chord, a considerable rate of change of lift with depth occurs, adequate to provide altitude control in calm water.

[2]Deep, fully-submerged foil systems have so little self stabilization that active control systems need to be used. However, hydrofoil craft equipped with such systems are capable of minimizing wave-induced motions in high sea states.

Emergency funds were made available in 1960 and the U.S. Navy accelerated its program of hydrofoil development. The reasons for this increased emphasis were related to the desire to increase the speed of surface units to keep pace with ever-increasing speed of other forms of platform, but particularly with the hope that hydrofoil craft would provide a more effective platform for coping with the high speed, continuously submerged nuclear submarine. Also, FY 1960 ship construction funds were allocated for the design and building of the HIGH POINT (PCH-1), a 120-ton hydrofoil patrol boat, built by Boeing (see figure B-1). Later, in FY 1962 funds were allocated for the design and construction of the PLAINVIEW(AGEH-1), a 320-ton experimental ASW hydrofoil ship, designed by Grumman and built by Lockheed. Finally, in early 1966, contracts were let for the construction of two Patrol Gunboat Hydrofoils, the 68-ton FLAGSTAFF(PGH-1), designed and built by Grumman, and the 58-ton TUCUMCARI(PGH-2), designed and built by Boeing. All the above craft have fully-submerged foil systems.

During the period from 1960 to the present there has been a continuing U.S. Navy Department program supporting research and development directed toward solution of problems and the generation of criteria for the design of hydrofoil craft subsystems including hull, struts and foils, propulsion, ship control, and auxiliary machinery. The results of much of this work have been incorporated in the design of present craft; however, much remains to be done toward the achievement of higher performance and increased reliability. The technical management of this Navy program is provided by the Hydrofoil Development Program Office in the Systems Development Department of NSRDC.

At about the same time as the Navy accelerated its program, the U.S. Maritime Administration, encouraged by the results of Navy research, decided to vigorously explore the possibility of increasing the speed of ocean transport through the use of hydrofoil ships. The results of this MARAD effort was an experimental prototype hydrofoil ship, the H.S. DENISON. This 90-ton, 60-knot ship was designed and built by Grumman. Completed in 1963, it was subsequently engaged in a program of demonstrating its capability at several Atlantic and Gulf ports. The DENISON is equipped with retractable, surface-piercing main foils and a submerged tail foil.

An example of the application of a fixed, surface-piercing foil system is offered by a 200-ton Canadian ASW hydrofoil ship HMCS BRAS D'OR. The ship was designed and built by De Havilland for the Canadian Forces. It was completed in 1969.

3. Design Considerations for Hydrofoil Craft/Ships.

To provide longitudinal stability of the craft, there must be lifting foils both forward and aft. These may be arranged so that most of the weight of the craft is carried well forward; such configuration is termed either conventional or airplane. Examples of this type of craft

are: PLAINVIEW, FLAGSTAFF, DENISON. Alternatively, the main foil may be well aft, with a bow foil carrying only a small part of the load. This is known as a canard configuration. Examples of craft embodying the canard configuration are: HIGH POINT, TUCUMCARI, BRAS D'OR. Again in some craft the load is almost equally divided between forward and aft foils, called a tandem configuration.

Lightweight Diesel engines are generally used for hull-borne propulsion. Also, most slower speed foilcraft (foil-borne speed $<$ 40 knots) have Diesel engines driving conventional marine propellers through an inclined shaft. Power for the foilborne operation of large high-speed hydrofoil ships is provided by the lightweight, marinized gas-turbine engines. Sub- and super-cavitating propellers as well as water jets are being used as propulsive devices. The hull material is almost exclusively aluminum alloy. Hydrofoil elements and struts are of fabricated and welded special-steel construction.

4. Air-Cushion Craft/Ships.

The second form of high-speed craft/ship considered here is the amphibious air-cushion vehicle (ACV). Although the concept itself, like that of the hydrofoil craft, is not new, its modern form is about 13 years old, stemming from Cockerell's invention of the craft with the air-cushion contained by a peripheral air jet forming an enclosing curtain. Present air-cushion vehicles depend on keeping a relatively static cushion of air below the undersurface for both hovering and cruising. The cushion pressure is sufficiently low, generally less than 0.7 psi, to provide support over surfaces of low bearing strength such as water, muskeg, swamp, or snow. Most of current ACV's are equipped with an elaborate system of flexible skirts. This enables an operation over rough seas or over hilly ground without danger of damage by impact. The majority of high-speed ACV's are propelled by controllable-pitch air propellers, either driven independently or combined with the fans which lift the craft. ACV's designed for lower speeds and water operation only still use marine propellers. Propulsion power for the ACV's, almost exclusively, is provided by the gas turbine engines. Present day structural requirements are essentially based on concepts and designs borrowed from the aircraft industry. Operational, and/or experimental ACV's, include sizes up to 165 tons gross weight. Some examples of current British ACV technology are such craft as the 7-ton SR.N5, the 9-ton SR.N6, the 37-ton SR.N3, the 76-ton semi-amphibious VT1, and the 165-ton SR.N4. These appear to perform well over uneven ground, marshy land, hard snow and water in moderately severe weather conditions.

There are currently at the Naval Ship Research and Development Center, in the Systems Development Department, two major programs concerning the ACV application. The first is the Amphibious Assault Landing Craft (AALC) Program. It is sponsored by the Navy Department and has the objective of defining, developing, demonstrating, and documenting

an appropriate air-cushion craft system for amphibious assault landing applications. Two different ACV configurations, of 150 to 160 tons gross weight, are being explored (figures B-2 and B-3).

The goal of the second program, Arctic Surface Effect Vehicle Program, is the development of a technological base of data necessary for the design and development of craft to provide mobility in the Arctic environment. This program is sponsored by ARPA. Some specific environmental problems for the Arctic are: temperatures down to -65°F, high ridges and ice packs, poor visibility, icebergs, high winds, electromagnetic disturbances, and others.

In general, some of the technical problems have to do with development of reliable propulsion systems, structure and skirt systems, and responsive control systems. A goal set for this Arctic SEV system is about 300-ton gross weight with an upper bound of 1,000 tons. Other bounds which are being considered are: speed from 60 to 120 knots and range of 1,000 to 3,000 miles.

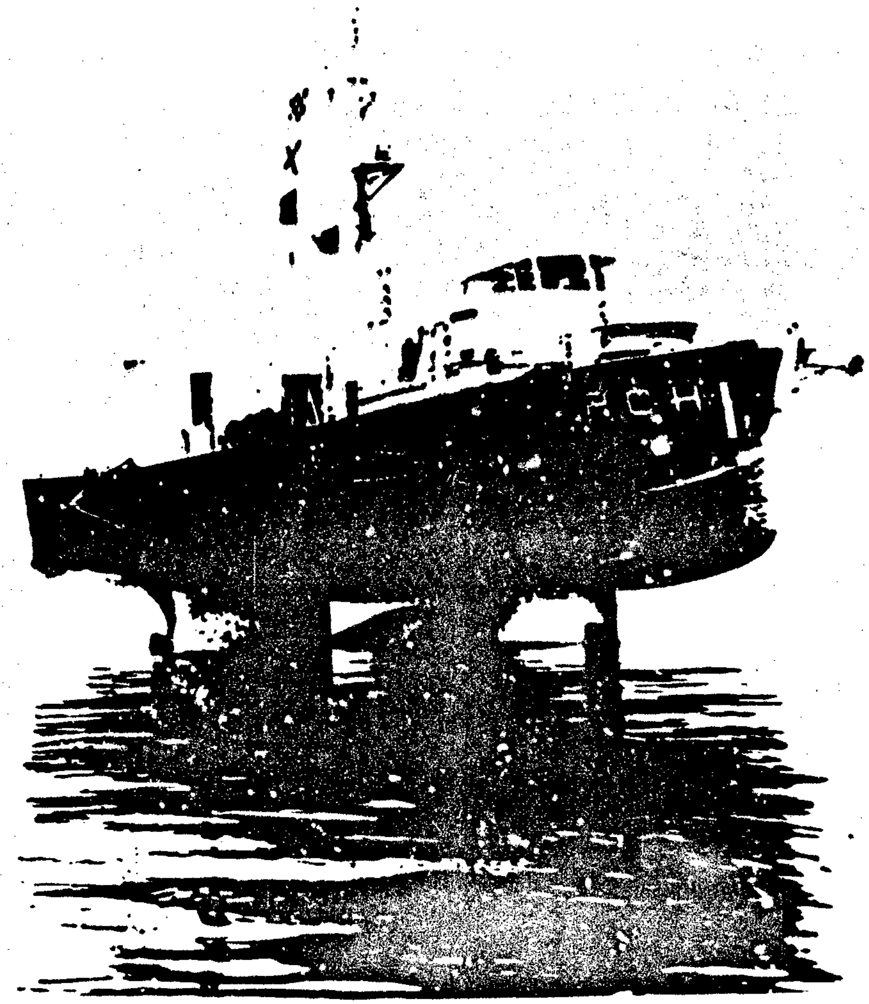


Figure B-1. The HIGH POINT (PCH-1)

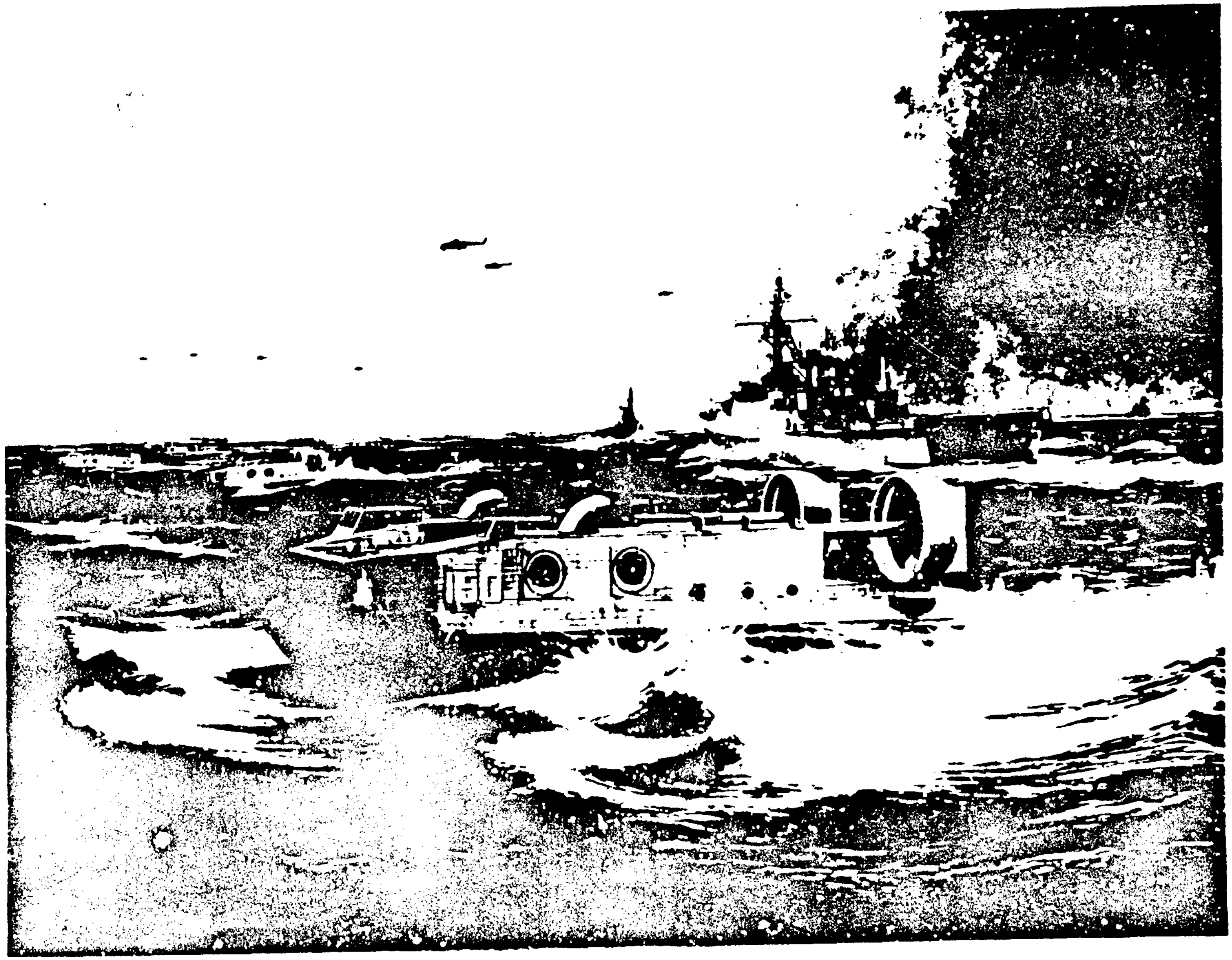


Figure B-2. Bell Aerospace Co. AALC Design

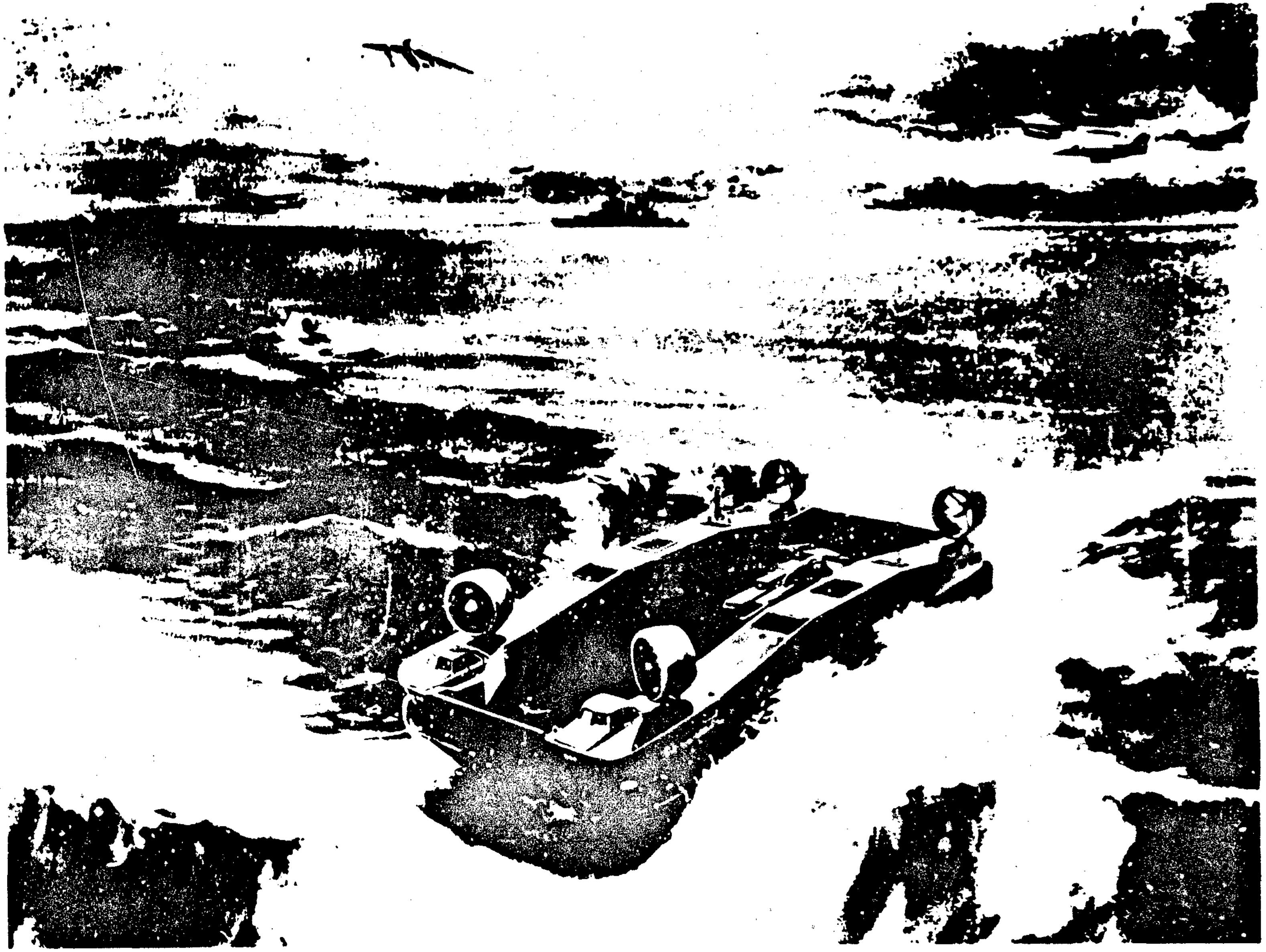


Figure Б-3. Aerojet General Corp. AALC Design

NOT REPRODUCIBLE

APPENDIX C

HIGH LENGTH/BEAM RATIO AIR-CUSHION SHIPS

by

Allen G. Ford
Naval Ship Research and Development Center

SUMMARY

I am going to talk about the high length-to-beam ratio air-cushion ship. Figure C-1 illustrates a possible application in aircraft carrier size. To meet an Army requirement, one might view it in the logistics sense as a carrier of materiel, having a transoceanic capability and a speed on the order to 50-60 knots. This is higher than present day ships but not necessarily aspiring to the very high speed potential of surface effects ships (100 knots).

This ship is primarily an air-cushion-supported class of vessel. Rigid walls retain this air support on the side, and seals of a flexible nature retain the cushion on the ends. The craft's roll stability comes from the sidewalls.

A problem that one faces with high speed vehicles is the efficiency of the craft. One way of expressing efficiency in a conventional craft, like an aircraft, is the vehicle weight- (or lift) to-drag ratio, W/D or L/D. When one talks about air-cushion supported vessels, one has to lower this number (L/D) a little from what it would otherwise be because energy is required to supply air to cushion the craft. Therefore, we speak of "equivalent lift-drag ratio." If you look for ranges of thousands of miles (e.g., transoceanic), then the equivalent lift-drag ratio, the power plant efficiency (i.e., specific fuel consumption in pounds per horsepower hour), and propulsion efficiency are all very important. The specific craft that I'm talking about, the high length-to-beam ratio, air-cushion ship, does aspire to high transoceanic range.

The surface-effect ship, as sponsored by the Navy SES Project Office (PM-17), is very comparable to this concept except that it has a low length-to-beam ratio. The implications of this will be discussed later. Each of the various types of developmental craft has its own advantages, speed regimes, developmental risks, etc. For example, the fully-submerged hydrofoil will probably end up being superior to this craft in the particular capability that it has; that is, its ability, in modestly small vehicle sizes, to operate in very high sea states. On the other hand, the hydrofoil probably cannot aspire to a high

enough lift/drag ratio to achieve transoceanic ranges of 4,000 miles or greater. Correspondingly, other craft have characteristics which are desirable. The displacement hull, in its very-low-speed regime, is a magnificently efficient vehicle. In both the United States and England, the hovercraft and air-cushion vehicle (ACV) business in general has gone from an impractical skirtless craft in the 1960's to a very useful kind of vehicle today. For example, the Navy sees substantial potential for skirted ACV's and has established the Amphibious Assault Landing Craft Program in order to utilize the high speed and amphibious characteristics of these craft.

At a previous AMCA ad hoc working group on air-cushion vehicles, the Army was very interested in looking at the direction the Navy was going in their amphibious assault landing craft program relative to their logistics-over-the-shore mission, and the Army displayed an interest in the overland characteristics of the skirted ACV. The ARPA Surface Effects Vehicle Program is also utilizing the overland and amphibious capabilities of the skirted ACV. The Navy SES Project Office sponsored vehicle is a side-wall class (captured air bubble) air-cushion-supported vessel, with a low length-to-beam ratio, and is aimed toward 80- to 100-knot speeds. The SESPO (PM-17) emphasis in development is on high efficiency, and fairly large vessels of the order of 4,000 tons or greater with transoceanic capabilities.

I'm going to narrow my talk to a specialized form of sidewall air-cushion supported craft, to one which is stretched out in length and which aspires to lesser speeds with somewhat higher efficiency and, also, a transoceanic capability. Figure C-1 shows a 13,000-ton vehicle with typical speeds from 50 to 60 knots, although higher dash speeds may be possible. Figure C-2 shows some of the design characteristics of this craft. In these figures, the craft is shown as a high speed aircraft carrier. In the Army's role one might well think of this as a high speed transport or cargo carrier.

If one is thinking seriously of transoceanic capabilities, basic vehicle efficiency becomes a very strong point. Figure C-3 shows the rationale supporting moving from low length-to-beam to high length-to-beam ratios. It is a plot of wave drag-to-weight ratio versus speed, one important drag term (but not total vehicle drag). An air-cushion-supported ship has a pressure region acting up and, when running, a component acting aft. This is fundamental in air-cushion ships, displacement ships, and, for that matter, in aircraft. When one has a low length-to-beam ratio, (or, as one would say about aircraft, a high aspect ratio) there is a hump at a certain non-dimensional speed (or Froude number).

The speed parameter in figure C-3 is the Froude number (speed divided by the square root of a constant times the length). This non-dimensional speed scaling parameter (Froude number) allows one to do

model testing in order to determine large-scale-ship characteristics. We can use this in the air-cushion field as well. To the extent that the drag, and hence the power, peaks but then drops rapidly at very high speeds (for an L/B of 2), one might go to the length-to-beam ratio of two in a design. To appreciate the speeds referred to in figure C-3, a destroyer would be typically at the non-dimensional speed (Froude number) of 0.5; an aircraft carrier would be a little lower (0.3) because it has a greater length; a typical displacement ship transport ship might be in the (0.2) range. The Navy has, in an existing program (the SES Program) taken advantage of this fact to aim at very high speed ships, 80-100 knots.

The specialized high L/B air-cushion-supported vehicle that I'm going to discuss resulted from considerations of operating in the intermediate speeds of about 50 percent higher than a destroyer in non-dimensional speed (with actual speed depending on vehicle length). In this speed regime, it is obvious that one should go to a very high length-to-beam ratio because in this Froude range the wave drag is prohibitively high for an L/B of two.

When one looks not only at the power that is required to overcome the wave drag but at the total power, it is evident that the low length-to-beam ratio is the way to go for high speeds; but when one looks at a calculation of the 10,000-ton vehicle in the 40- to 60-knot regime, the high length-to-beam ratio appears to be the logical choice. Therefore, an effort in this area was initiated by the Naval Ship Research and Development Center, and a 15-foot model was built (figure C-4). One thing that this experiment with the 15-foot long model has brought out is that we are dealing successfully with high efficiencies. I have one of the little fans that were used in the process of optimizing calm-water power. About three of these little fans were required in smooth water, and about twice that number in rough water. These fans are about equivalent to a 25-watt light bulb in power consumption. Efficiency is the name of this particular game and we are playing it in just that way.

We have shown in the experiment over the past year a substantial increase in efficiency relative to the destroyer. Secondly we have shown that this is not only an absolute improvement but that increasing speed results in a much shallower slope in drag and powering, relative to the displacement hull. These were the two objectives we had in the smooth water test. Although the project is not terribly far along, the results are promising. The results are especially promising for vehicles that operate at speeds of about 140 percent of the non-dimensional speed of a destroyer (i.e., Froude number of about 0.7); of course, the absolute speeds depend on length as well. So we might well be talking a range of speeds from 40 to 70 knots. These speeds may be possible with transoceanic capabilities and enough efficiency so that we would not have to carry excessive fuel and little payload.

But, the effort is in an early phase, and although we think it is looking very positive at this point, there are obviously many things that have not been done. On the basis of the evidence that we have so far, we have obtained rather enthusiastic in-house NSRDC programs for the coming year. We have funding to look at powering of the vehicle, motions, stability of the craft, structures, and machinery and propulsion. With inputs such as these it will then be possible to assess the utility of these craft in Navy missions.

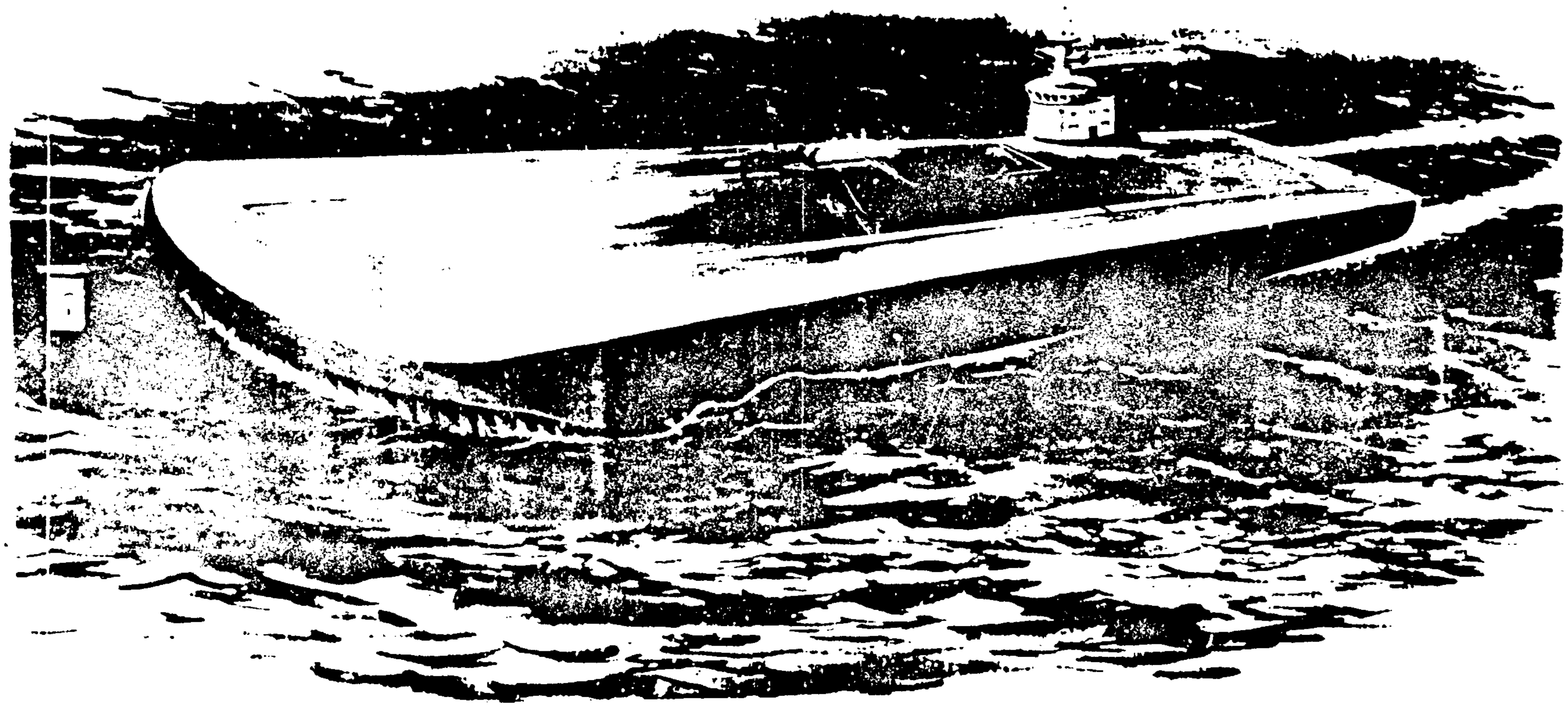


Figure ?-1. Application of a high length-to-beam ratio air-cushion ship as an aircraft carrier.

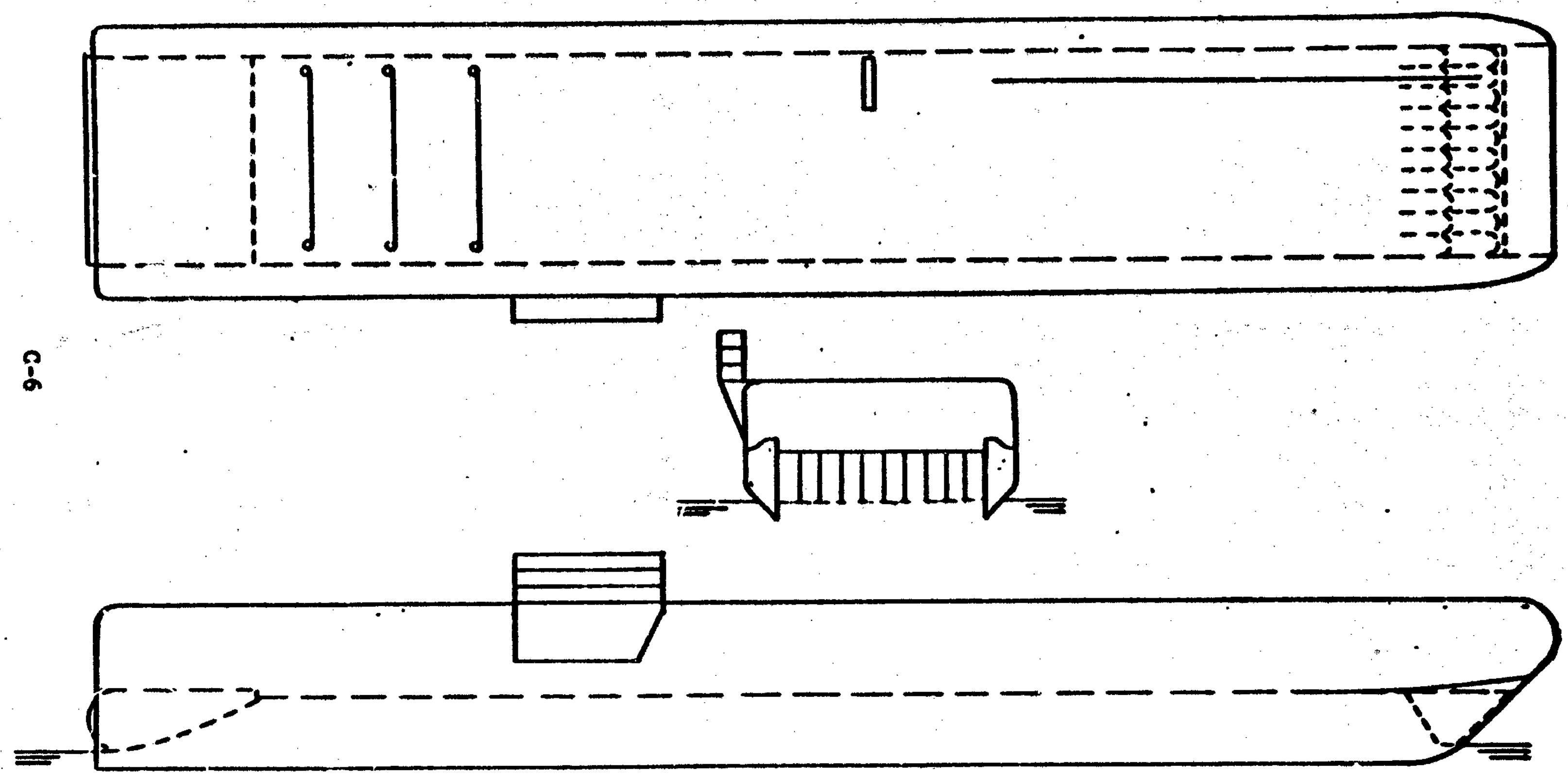


Figure C-2. High length-to-beam ratio air cushion ship projected characteristics as an aircraft carrier.

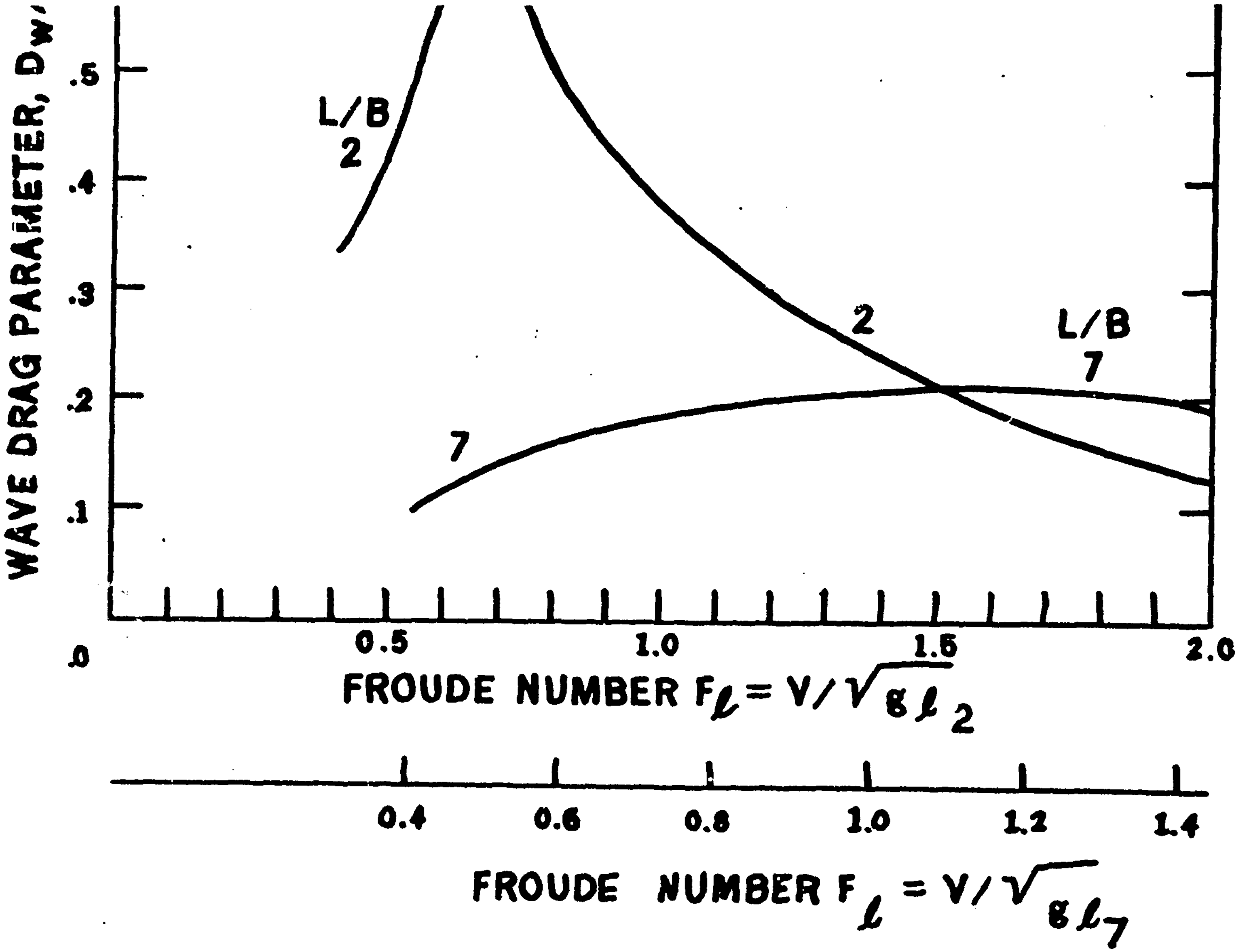
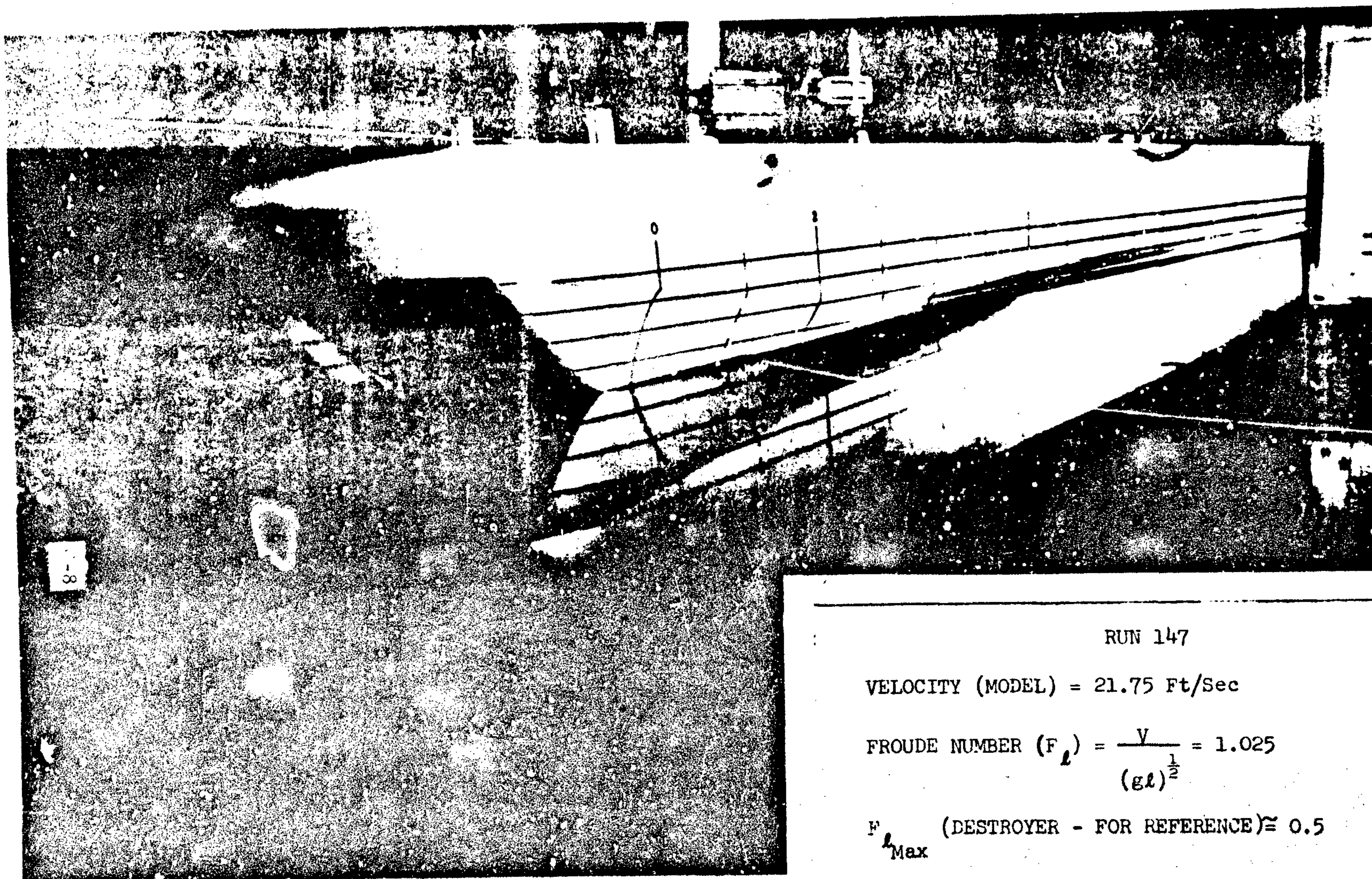


Figure C-3. Comparison of cushion generated wave drags (at the same speed) for two length-to-beam ratios.



RUN 147

VELOCITY (MODEL) = 21.75 Ft/Sec

FROUDE NUMBER $(F_{\ell}) = \frac{V}{(g\ell)^{\frac{1}{2}}} = 1.025$

$F_{\ell_{Max}}$ (DESTROYER - FOR REFERENCE) $\cong 0.5$

ℓ_c (Cushion Length) = 13.83 Feet

NOT REPRODUCIBLE

Figure C-4. Picture of high L/B air cushion ship model operating at about twice destroyer non-dimensional speed.

APPENDIX D

SEAPLANES

by

Richard D. Murphy
Naval Ship Research and Development Center

SUMMARY

If there is a proponent of seaplanes in this room, he would probably start out by reminding you that the majority of the surface of the earth is covered by water. And he would be quick to point out that 80 percent of the cities of the United States are either on suitable water (rivers, lakes, or the ocean) or have reservoirs or some suitable water surface relatively close to the city from which seaplanes can operate. And he will go on to say that almost every center of population in the entire world is equally endowed. However, he might fail to point out that the surface of most of that water is inhospitable to seaplanes.

The first problems of seaplane design concerned the water surface. When the Navy retired its last operational squadron of seaplanes, we still had the surface problems with us. But in the meantime the seaplane had enjoyed a real heyday. There has been nothing to match it. The seaplane had set records in endurance, range, load; yes, and in comfort, luxury, and safety. Unemcumbered as they were by takeoff field-length criteria, or obstacle clearance after takeoff, they grossed 10-50 percent above land planes. A lot of that gross weight turned out to be an increase in volume, and that was the way that luxury was built in the aircraft. However, the relative heaviness with low power gave seaplanes the name of "lumbering bathtubs," which I don't think is quite fair.

Let's look at some of the more recent history of seaplanes. Five PBM Mariners were anchored 9,200 yards off of Saipan within 48 hours after the Marines and the Army had landed on Saipan in World War II. The land facing the anchorage was all enemy held. They were under gunfire and out that far they were operating in the open ocean. At dusk on the day they arrived, they were on their first operational radar search mission. It was the only air support we had then in that area; we were too far from anything from which land planes could operate.

I'd like to skip forward into 1946 and 1956. The Navy operated four Martin Mars, the JRM family at 165,000 pounds gross weight. In

1946 I thought I flew a pretty heavy aircraft when it grossed out at 67,500 pounds. The Mars was more than twice the size of that aircraft. It would cruise at 215 miles an hour and set a distance record of 4,748 miles from Honolulu to Chicago carrying a little over 14,000 pounds of cargo and 42 people. And the Mars in 1950 carried 301 men from San Diego to Alameda, California. Then there is the R3Y. This was the only turbo-prop seaplane that the Navy had. I think it was one of the very few in the world. It needed a very large engine because it was a pretty large machine -- 175,000 pounds gross weight. It could cruise at 300 miles an hour with a 4,000-mile range; but it used the only large engine that we had at the time, the P-40, and everything that used the P-40 had trouble. This engine had a very long, coaxial shaft. We've always had trouble building counter-rotating props in this country and, as a result, the aircraft did not fair too well. When they converted the aircraft, they gave it a drive-in bow. Now, you wouldn't mind driving a track vehicle in and out when the water is calm; but sitting in a heavy surf, you might think twice before you climbed those rails.

The Navy had something to do with the development of an aircraft which would surpass in performance the B-47 and it was a contemporary of that aircraft. I happen to be a friend of the test pilot that flew this aircraft, number 3 in the P6M series. Number 3 aircraft, according to this gentleman, flew like a dream. The books say it had a gross weight over 150,000 pounds, but my friend, who has been known to stretch a story, says it grossed 210,000 pounds which would make it a very large seaplane. The cruise speed was in the order of Mach .87 or .88 at 40,000 feet. It had a beautiful takeoff -- 45 seconds off the water -- and that's a pretty good target value for conventional seaplanes. It would get off in 5,000 feet. It had an approach velocity of something like 95 knots, and was a lumbering, safe, easily controled airplane on approach. And, as my friend says, it would outperform the B-47.

We have to look to Great Britain for the largest of the seaplanes. The largest that I know of was the Saunders Row Princess. It grossed 345,000 pounds and was sort of Britain's B-70 program. They started and stopped, started and stopped, started and stopped, until it finally flew in 1952. The aircraft had a useful load of 173,000 pounds. It would fly 5,250 nautical miles with a 50,000-pound payload. But these giants were all sheltered-water vehicles. The surface has always provided the severest constraint for seaplanes.

Well, finally, after the aviation glamor had transferred to the land planes and their amazing performance, we began to look at the surface problems for the seaplane. An old Grumman Widgeon (figure D-1) was outfitted with at least a dozen different hull shapes. One of these is called a high-dead-rise, long-after-body, planing-tail hull (to a hydrodynamicist, I suppose that means something). Essentially, the

high-dead-rise means that it doesn't impact on a wave quite so hard, and the planing hull and the long-after-body gave it better control on the water and better takeoff characteristics. Figure D-2 is one aircraft that was flown, an experimental hull on the Martin P5M series. This had a number of modifications on it; full outboard leading-edge flaps, some aerodynamic changes (notice that no positive break step was required), and a 15-1 length to beam ratio, giving some very good aerodynamic and hydrodynamic characteristics.

And then someone got smart and said, "If you're having trouble on the surface, why don't you get the heck off of it." Figure D-3 is a Grumman Goose; a JRF in Navy terminology. They put a V-shaped hydrofoil underneath it. The problem is that the hydrofoil was almost always too large. The two booms out in front are confidence devices. The aircraft experienced a number of rather interesting events. Seaplane pilots were naturally the first to test fly it; but if a seaplane pilot notices the nose of his aircraft going down, he reacts by chopping the power. So every time the plane was just about to get up on its foil, the nose would go down and he would cut the power. The booms were supposed to convince the pilots that the nose wouldn't go under, but they didn't believe it. Finally, the test manager went to the officer's club and recruited a land-plane pilot who had never made a water takeoff in his life. And you know that the nose goes down on a land plane when you put it up on the gear. The pilot got into the seaplane, found out how to operate it, pushed the power levers up, and when the nose when down, prepared to takeoff. There was simply a need to break an old pattern.

Figure D-4 shows dual hydroskis on a Grumman Goose. Actually this solved another problem with seaplanes. If you put small wheels on the skis you have a built-in beaching gear right on the aircraft. But the double skis didn't work out too well, so they went to a single ski. And why not? You've got this aerodynamic control device (the airplane itself) on top of the ski; so just fly the airplane.

Thus, an awful lot has been done. There's a vast amount of research that says we could have a large seaplane. The engineering developments certainly should have led to some concepts, so let's take a look at a couple of them. Martin proposed a supersonic seaplane concept. We've tested another one in our wind tunnels at the Naval Ship Research and Development Center. Figure D-5 shows the C5-Sea, for lack of a better name. All these studies were completed and most of them have been forgotten, unfortunately. It is interesting to compare this concept with the actual front-end-loading R3Y (figure D-6).

The problem of stabilizing a floating seaplane is difficult. A solution is to stand it up on vertical floats. Figure D-7 represents an aircraft loaded to about 55,000 pounds gross weight. This is a rigid set of cans and, therefore, unsuitable to a flying aircraft in its present form. When that aircraft was loaded to represent something

in the order of the mass and weight distribution of an 80,000-pound seaplane, it sat free but lower in the water. But you could get aboard that aircraft and sit 24 hours a day, and you'd think you were in an easy chair at home. Motion was almost inperceptible. At the time these tests were conducted there was another PBM sitting on its hull a short distance away and they took crews and interchanged them, ship-to-ship. Well, they tried to. The people on the surface ship were constantly seasick, the motions were so violent.

Figure D-8 shows how a PBM-sized aircraft was envisioned to operate for the Navy on vertical floats. These floats are rubber tubes, and they can be retracted into the aircraft in the center of the hull, or into the tip floats. I've done some design work involving these, and found that if the manufacturers can do what they say they can do, it's a very workable system. It doesn't take up a great deal of space. The cycle time on the float extension has been postulated to be 30 seconds and you're up out of the water.

One more area that's now being investigated is air-cushion landing gear. It might be very, very nice for a seaplance to come in over the surf, sit down on the sand and unload. This is just now being looked at in the Navy laboratories.

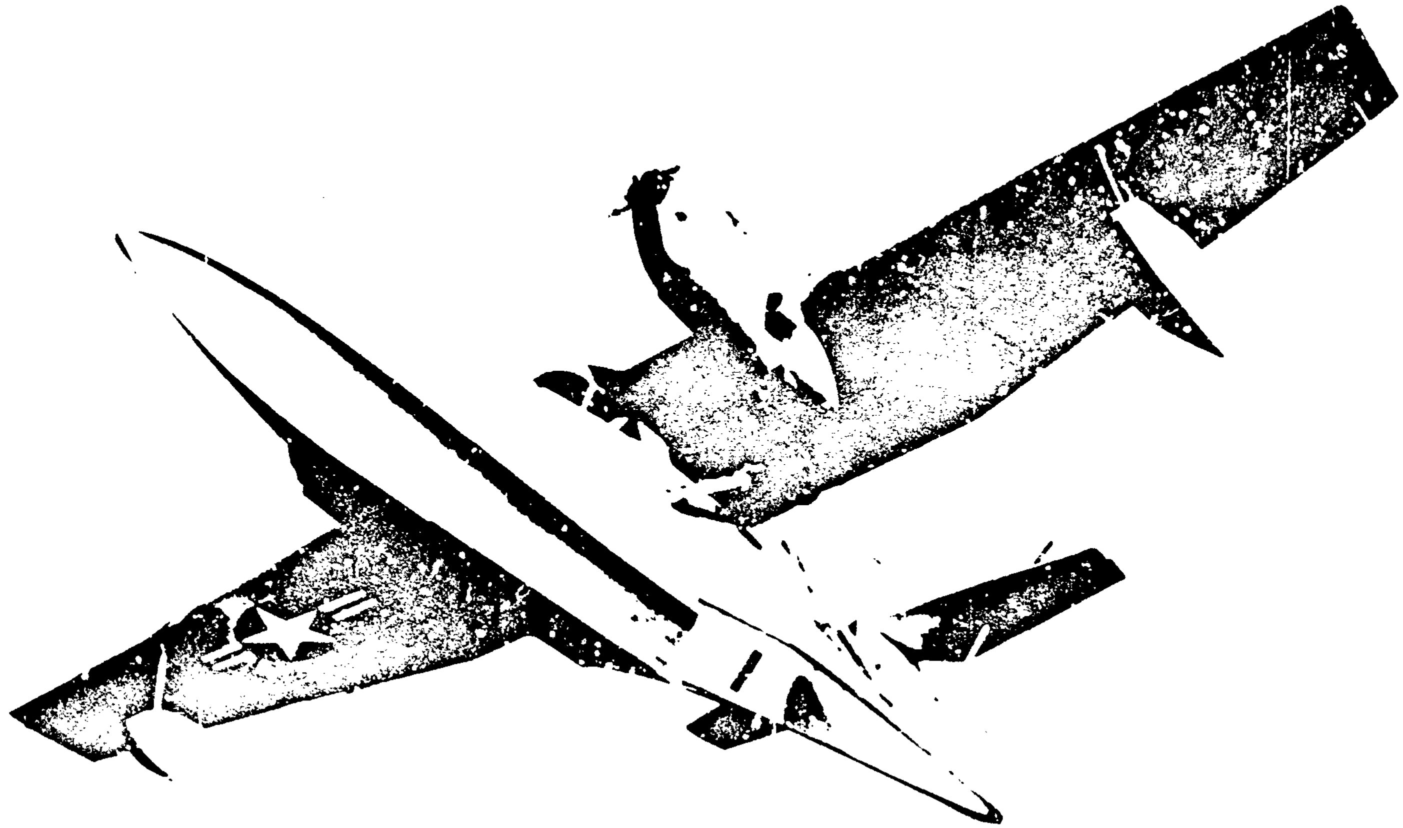


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Figure D-1. Grumman Widgeon with a high-dead-rise, long-after-body, planing-tail hull.

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Figure D-2. A Martin P5M modified to incorporate an experimental hull.

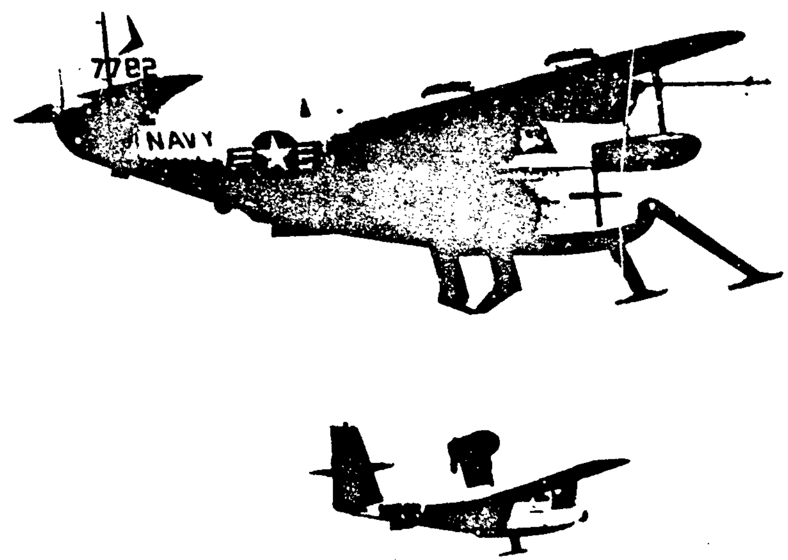

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Figure D-3. A Grumman Goose (foreground) fitted with a V-shaped hydrofoil.

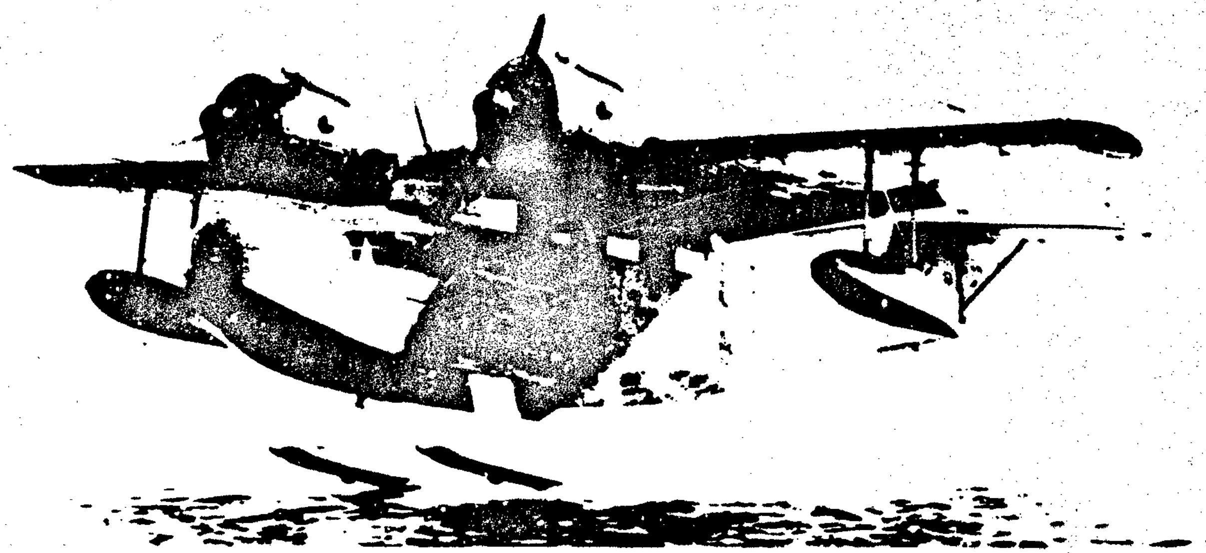

Figure D-4. Grumman Goose with dual hydroskis.

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Figure D-5. Concept for a supersonic seaplane.

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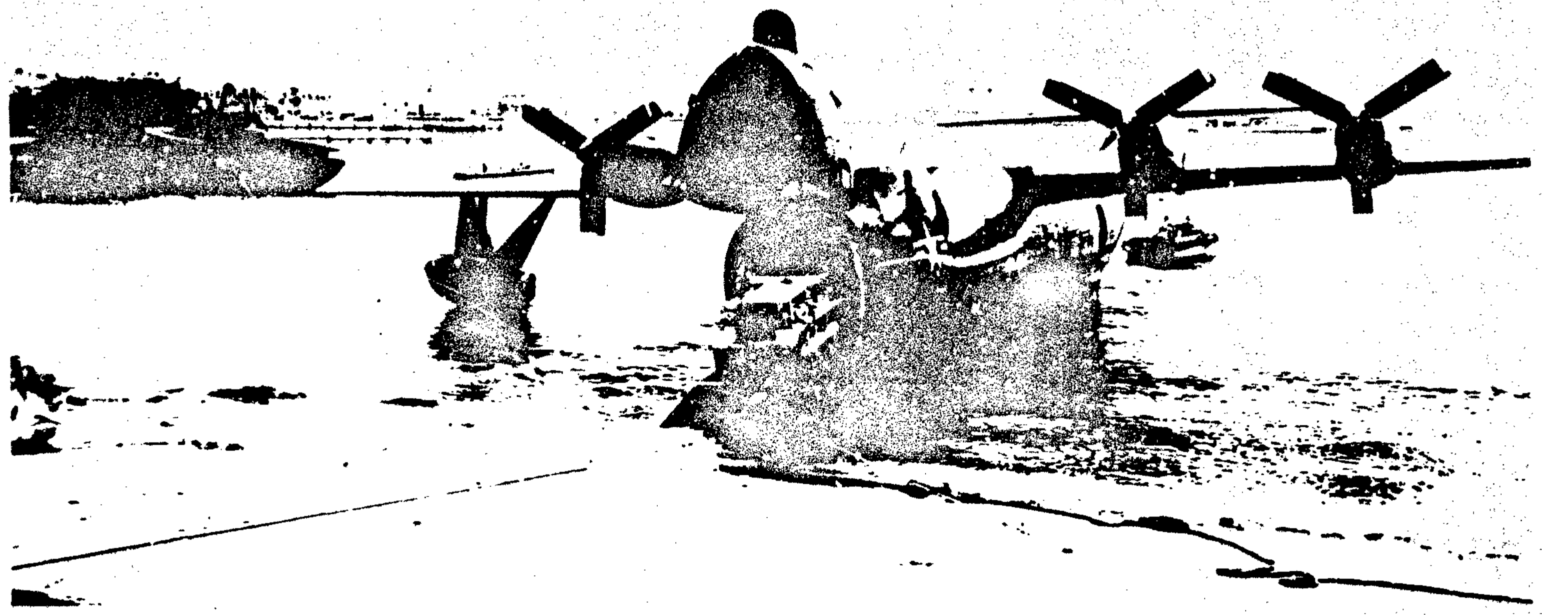

Figure D-6. The R3Y, illustrating the usefulness of the drive-in bow.

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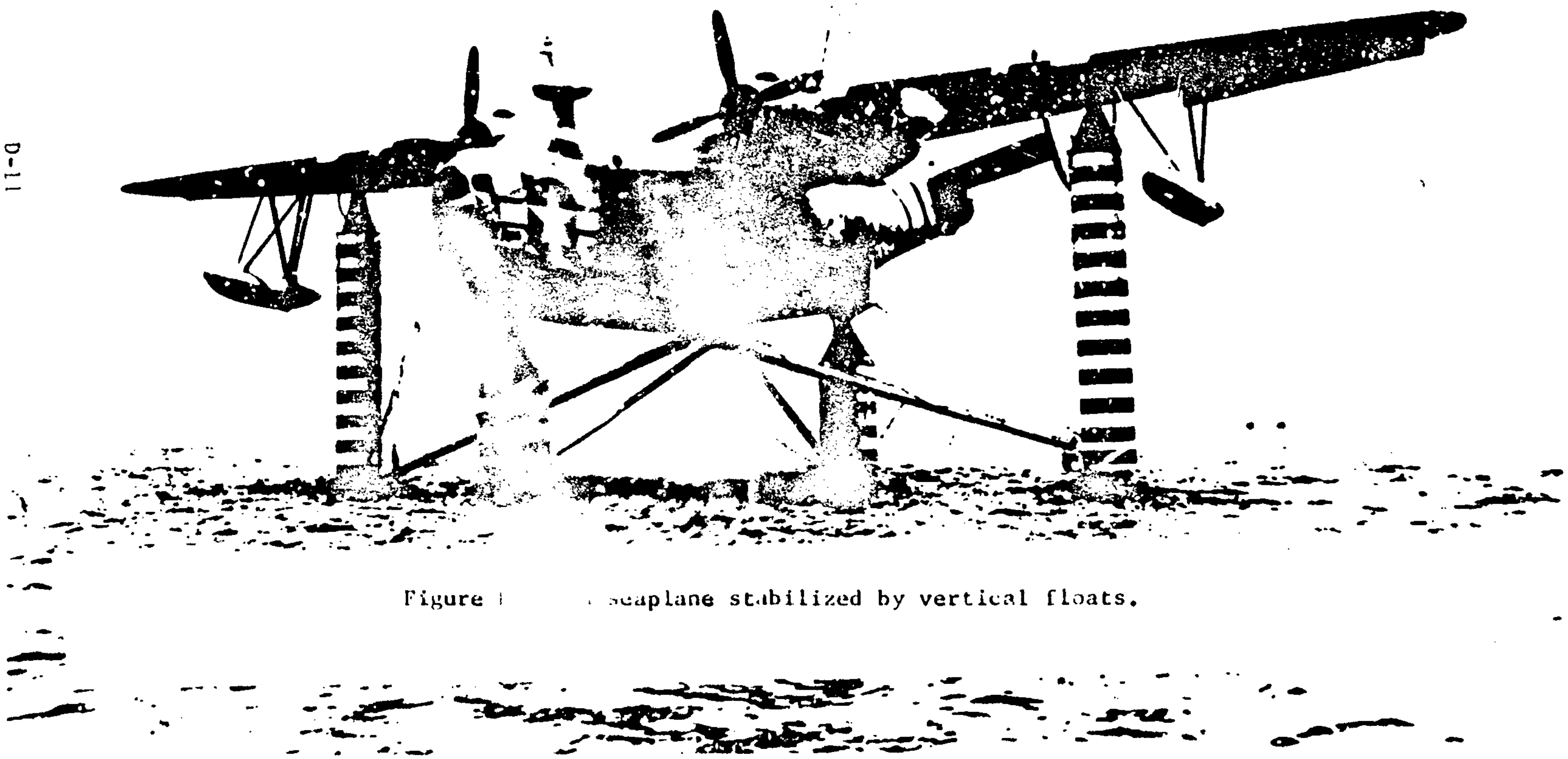

Figure [illegible] seaplane stabilized by vertical floats.

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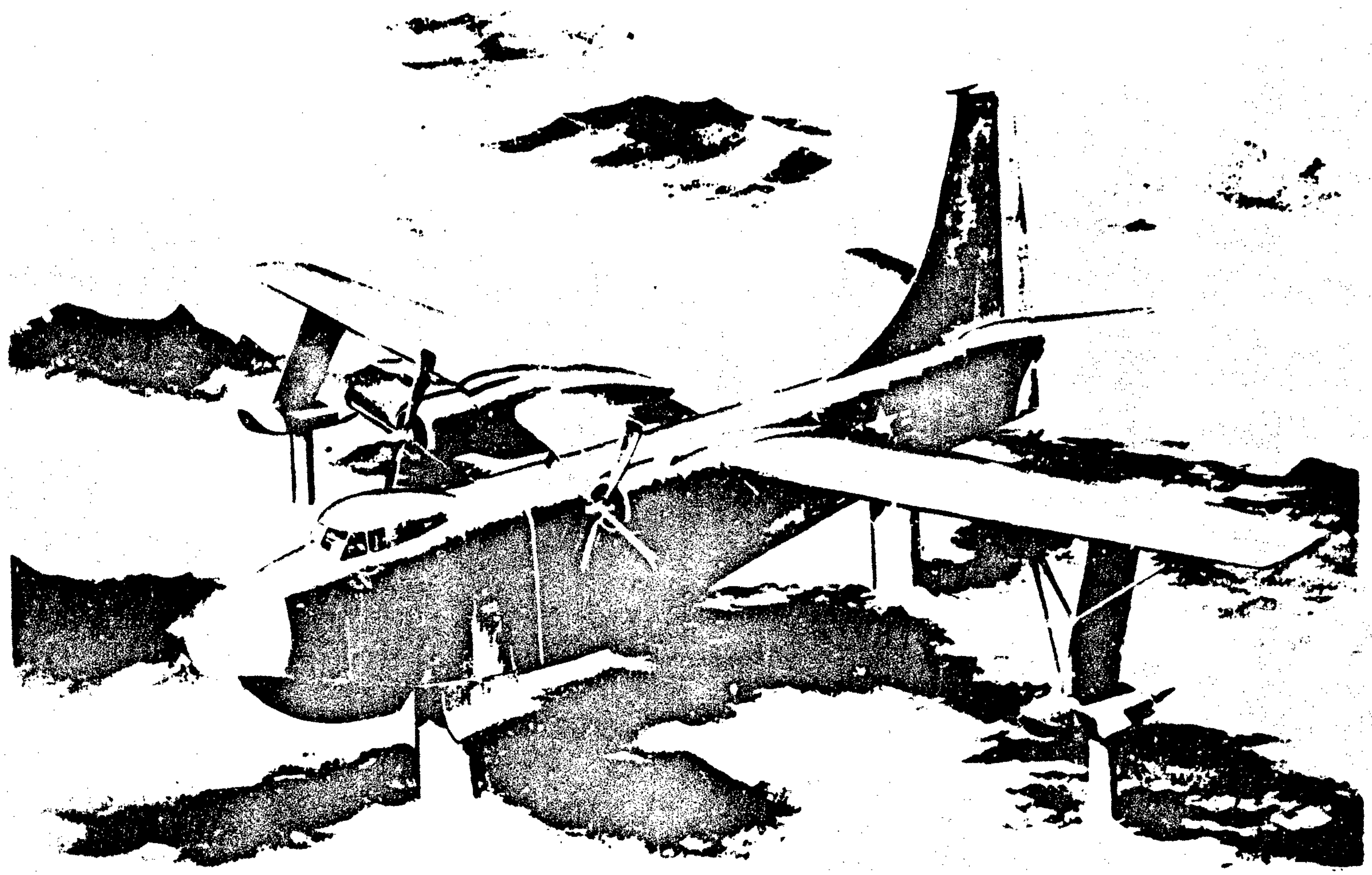

Figure D-S. Artist's concept of a PBM-type seaplane supported by vertical rubber tubes.

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APPENDIX E

HIGH SPEED DIRIGIBLES

by

Dr. Robert Ross

"Dirigible" is the correct word for that group of balloon-like vehicles that can be propelled and steered. However, the general term usually used is "airship," with the connotation that those with rigid hulls are dirigibles or zeppelins. The term "high speed" is defined as a speed significantly greater than the speeds associated with airships of the past. We can anticipate high speeds relative to ground transportation carrying comparable payloads.

This paper is concerned primarily with what can be called "Little Known Facts" regarding lighter-than-air technology and its potential capabilities. A few of these are listed. Following this, it is shown how these facts can be exploited to produce a new breed of advanced vehicles with extremely attractive operational performance capabilities. The facts are:

- Helium is in plentiful supply today, eliminating the risks associated with use of inflamable hydrogen.
- At the time of the airship losses, weather forecasting was in its infancy.
- The comfort level in airships is unsurpassed by other transportation vehicles. Airships do not even require seat belts.
- Airships can be all-weather aircraft and have demonstrated this capability in missions performed by the Navy.
- For station-keeping and patrol work, airships are particularly useful and have established many records. One was the 11-day non-refueled flight of a Navy "K"-type airship.
- The airships can be designed to fly heavy and operate with minimum ground crews.
- Quiet, pollution-free propulsion is possible because of the size of the vehicle, the location of the powerplants, and the amount of power required.

- Airships can operate in and out of relatively small fields if they are given VTOL (vertical takeoff and landing) capability.

- Airships can carry large and heavy payloads internally or externally, and can be designed to utilize a rigid or non-rigid envelope, depending on the mission requirements.

- Nuclear-powered LTA (lighter-than-air) vehicles are feasible and can result in higher speeds than previously considered possible.

By means of a number of illustrations, the transporter potential that lies dormant in the existing LTA technology will be shown. Figure E-1* is a photograph of an advertising airship that Goodyear is flying today. These airships are primarily goodwill ambassadors carrying giant multi-colored signs or TV cameras. The airship, itself, however, is basically a 1930 model with an exceptional safety record.

One of these older advertising airships was modified to operate silently. Figure E-2 shows the installation of this stern propeller with its slow-turning blades. It was possible to operate the vehicle at slower speeds and more silently than ever in the past. Actually, it was not possible to hear the vehicle on the ground, even when operating at a relatively low altitude. Even today there are applications for this type of aircraft operating in a silent mode, with a maximum speed of 55 mph. It could be fitted with a glass-bottom passenger compartment, as an observation vehicle to carry tourists over African parks, much as a glass-bottom boat. Nature could be observed without the disturbance of noise. As a military application, one can readily see the advantage of patroling areas silently and quickly, particularly at night.

As soon as bigger LTA vehicles are considered (and it is wise to do so since the lift increases as the volume while the structure is a square relationship), one immediately sees the possibility of carrying extremely large payloads. Figure E-3 shows a transporter for a huge rocket booster, uninhibited by bridges, roads, or other terrain limitations. At one time it was even considered worthwhile to interconnect two existing airships to raise the payload capability so that a booster could be carried from factory to launch site. The vibration-free trip would result in a delivered item with high structural integrity. Once one starts thinking big, it becomes practical to examine where such vehicles might be built, and to innovate around such limitations. One might even consider a vehicle with external ballonets. These ballonets would not actually be filled until the vehicle left its hangar, since they only contain air on the ground anyway. With this approach, the Akron hangar might be used to build ships up to 18,000,000 cubic feet.

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*The illustrations in this paper were furnished through the courtesy of Goodyear Aerospace Corporation.

The early rigid airships, like the Akron and the Macon, had a vertical takeoff capability with swiveling propellers. As a matter of fact, they had no wheels for any type of ground run. It is probable that LTA vehicles of the future would have this VTOL capability, but to a much greater degree. The last airships built for the Navy had retractable tricycle landing gears, very much like airplanes. This permitted them to operate up to 10,000 pounds heavy, and to make takeoffs and landings much like STOL airplanes. This meant that while on the ground, standing on their tricycle gear, they did not need a ground crew to hold them. This extra weight-carrying ability that was provided in addition to the lift of the gas, permitted a sizable range increase without the usual worry of ballast pickup as fuel was expended. With the use of ballast pickup, it was possible to take off heavy and return heavy, in spite of fuel usage, permitting an airplane-type landing with flair, and reverse pitch propeller braking.

The extent of designed dynamic lift or heaviness depends on the airship's mission and practical operating requirements. There are many ways of obtaining dynamic lift, and no finite value has been set on what percent of the total lift should be static lift from the gas or dynamic lift from the shape of the vehicle. One thing is quite definite; the use of dynamic lift makes the LTA vehicle much more versatile and easier to handle on the ground. Once the dynamic lift principle is accepted, and sufficient power is included for a vertical takeoff (either through the use of a deflected slipstream or tilted propeller principles) the on-board power can be used for increased speeds in a horizontal direction.

A 20,000,000 cubic foot vehicle, with nuclear power, might actually achieve speeds up to 200 mph, with payloads approaching 1,000,000 pounds. The shape this vehicle would take could only be conjecture at this point. It would depend on many things, but primarily the mission and the kind of payload to be carried. Figure E-4 is an artist's concept of how this giant LTA vehicle might look. It could be just a flattened version of what we have known for a long time. The reason for the flattening affect is to give better dynamic lift without the need for a large angle of attack.

A caricature of a VTOL LTA vehicle with dynamic lift capability, often called a Dynastat, might show it with a flattened envelope, lifting wings, giant stern propellers, lifting fans, and plenty of control surfaces. Studies are needed now to determine the best configuration. Figure E-5 is an artist's caricature of a Dynastat.

Because of the low operating altitude generally used by lighter-than-air vehicles, it is entirely practical to consider that they would perform in a realm not now controlled by the FAA. Figure E-6 indicates how this might occur where runways at airports were used by airplanes. and helicopters and VTOL aircraft could utilize landing pads on buildings or in parking areas. This would alleviate much of the air traffic control problem encountered today.

Safety is one of the big features of the airship. It uses multiple engines and can easily operate, or even hover, with only partial power. With no power, it can glide to a landing.

If one were to consider nuclear power, it is possible to think in terms of higher speeds. This is because a minimum size and weight engine can supply sufficient power to achieve the higher velocities without a significant weight penalty. This is illustrated in figure E-7, where the weight is shown to be substantially the same for a sizable increase in thermal power. Once a nuclear vehicle is considered, personnel limitations become important, including supplies and endurance, rather than just equipment operating-time limitations.

Figure E-8 merely indicates that it is possible to make large vehicles without encountering excessive costs. Actually, since the relative performance goes up with size, the cost per unit payload will probably go down. This is a good reason to consider large LTA vehicles.

Figure E-1. Goodyear airship

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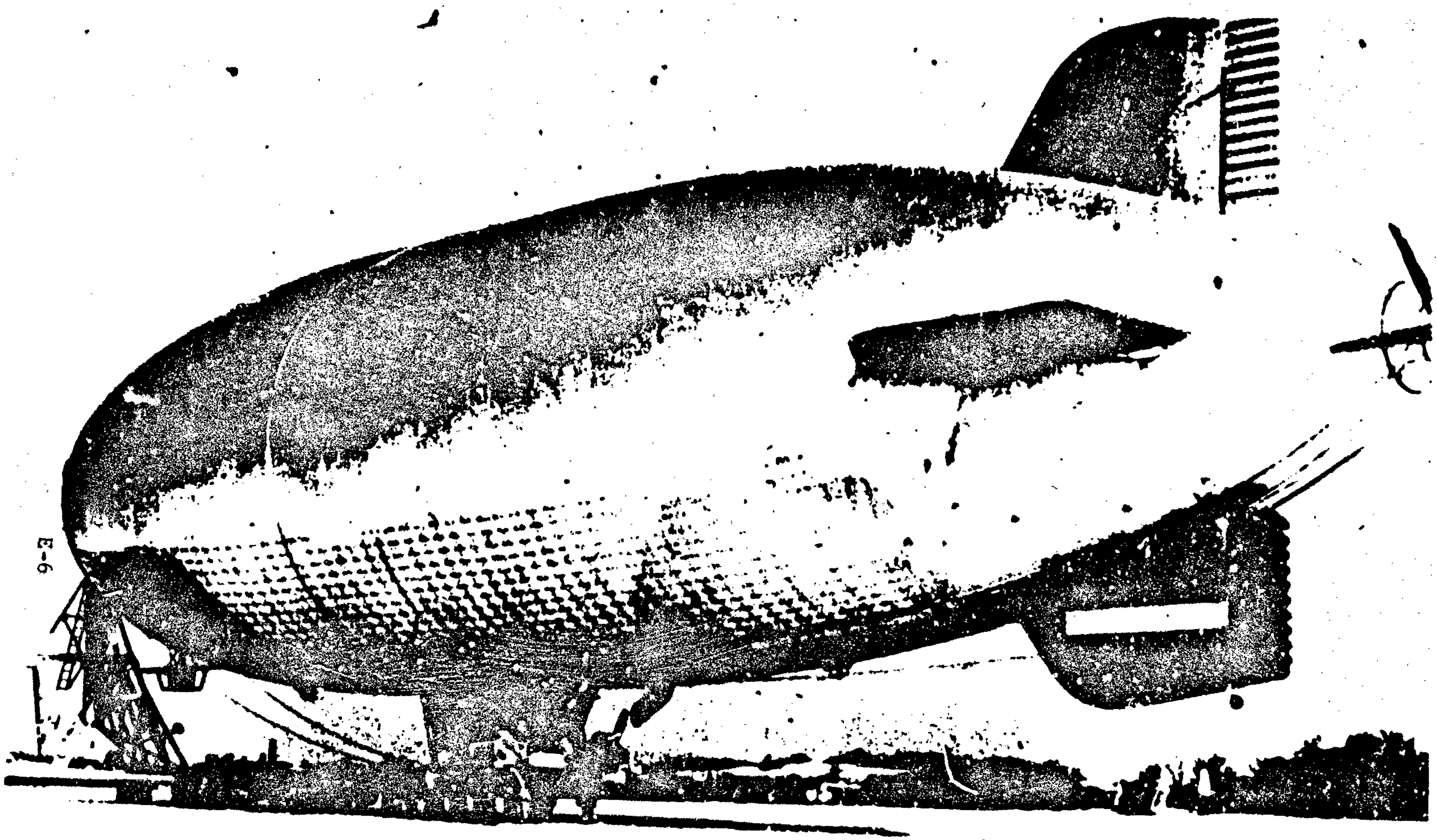

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Figure E-?. Airship with stern propeller

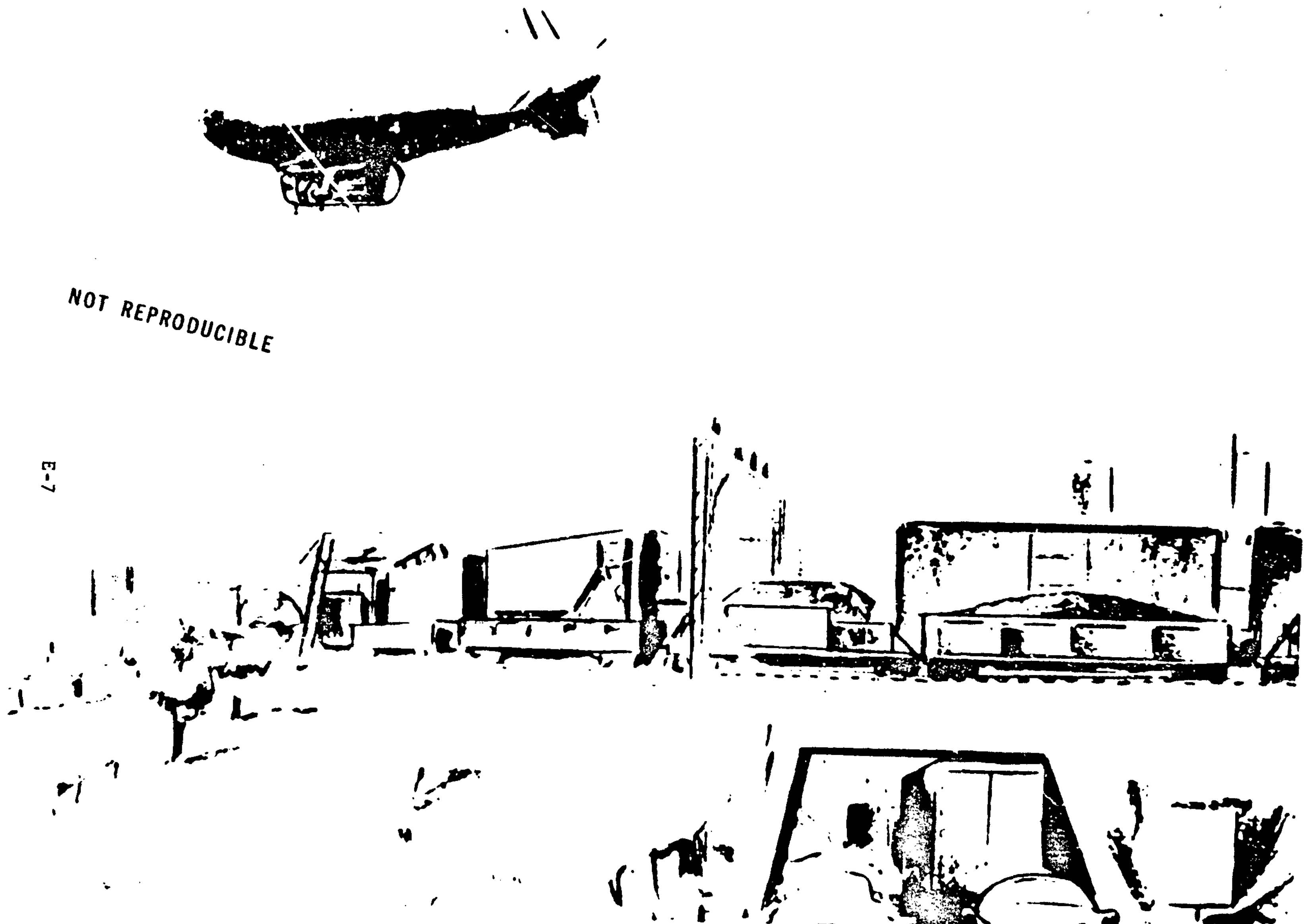

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Figure E-3. Airship transporting outsized cargo over conjested area.

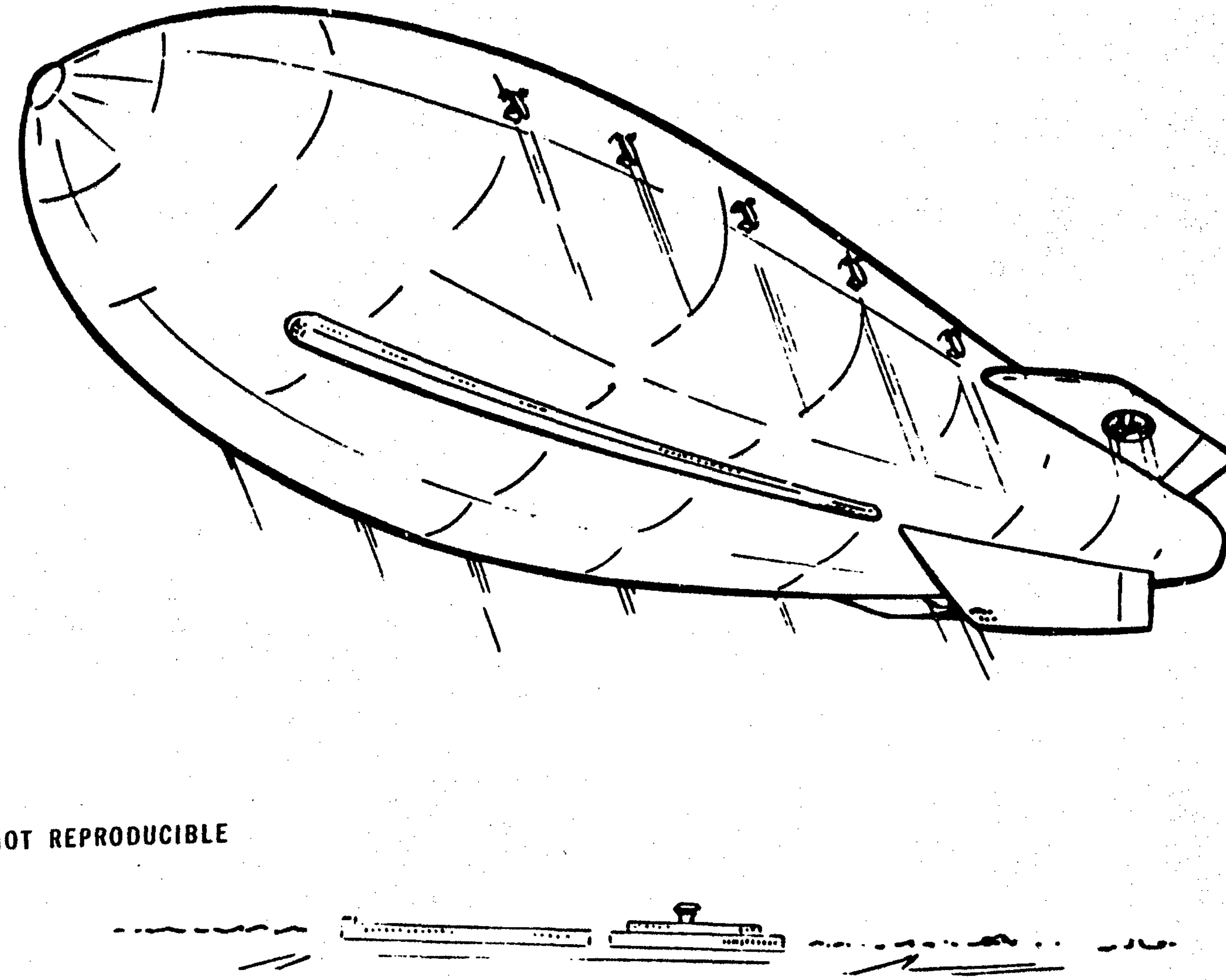

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Figure E-4. Artist's concept of a fast, high payload airship.

NUCLEAR-POWERED DYNASTAT

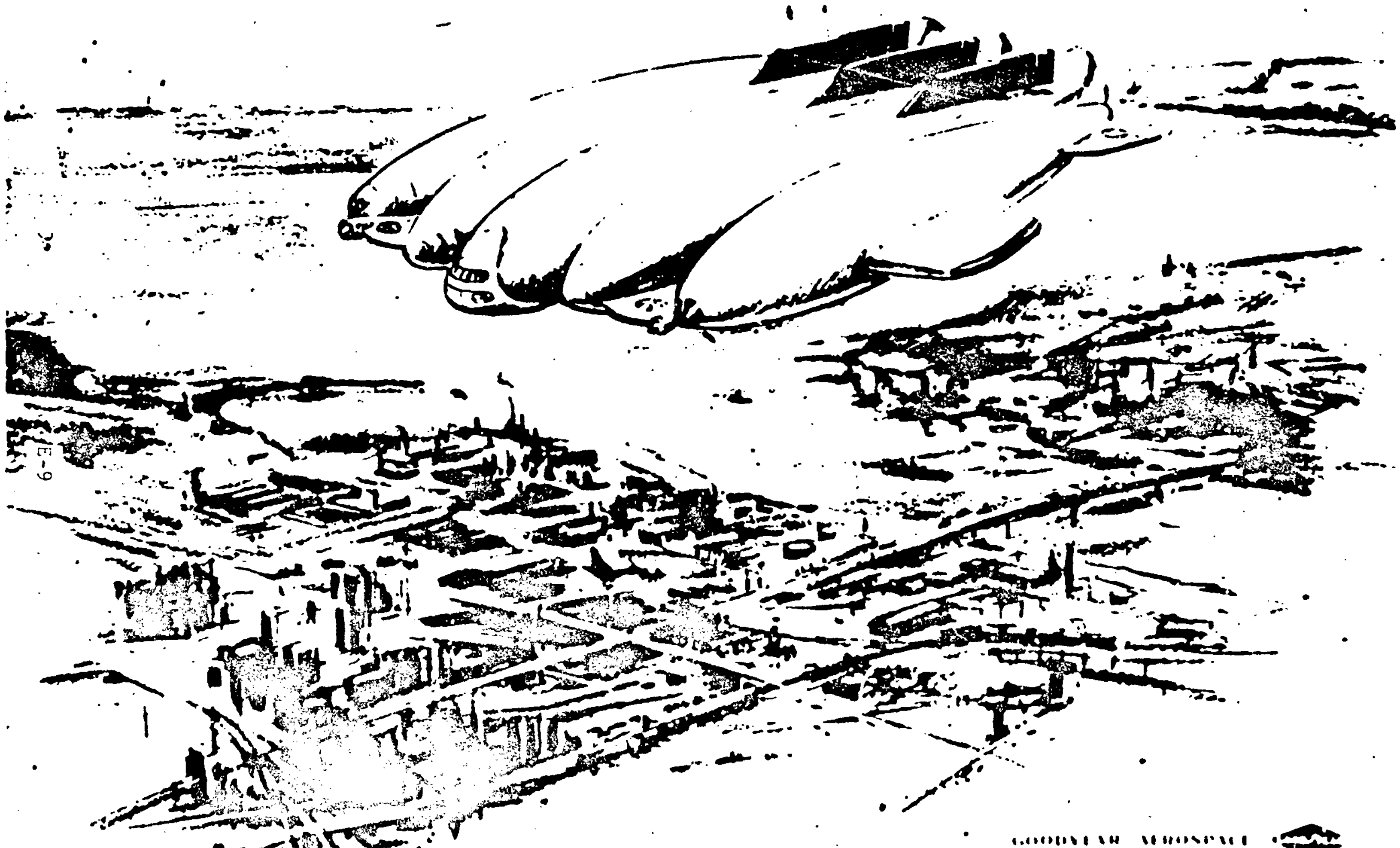

Figure E-5. A [illegible] concept of a dynamic-lift airship.

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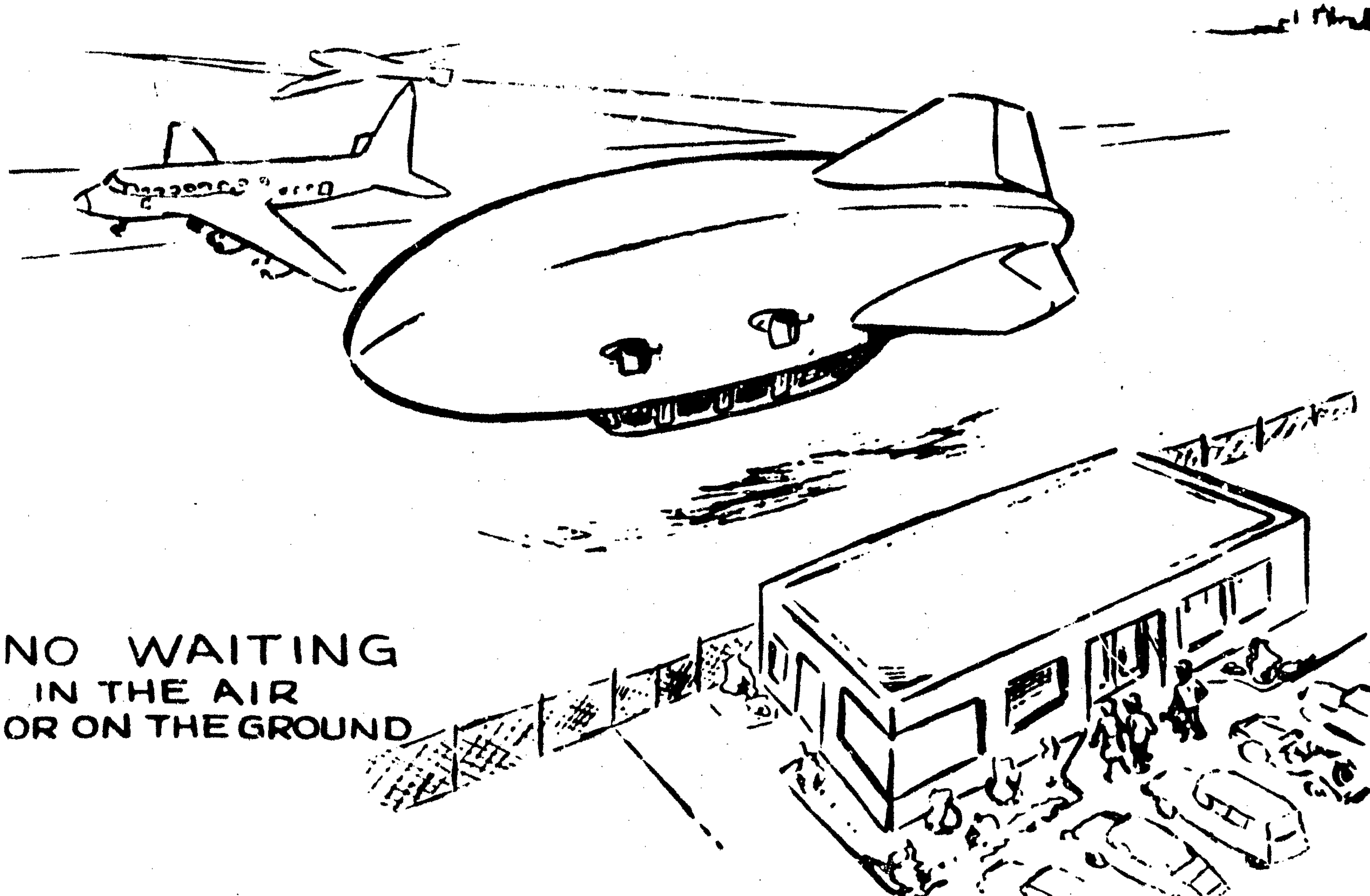

Figure -. Employment of airships to reduce congestion in airports.

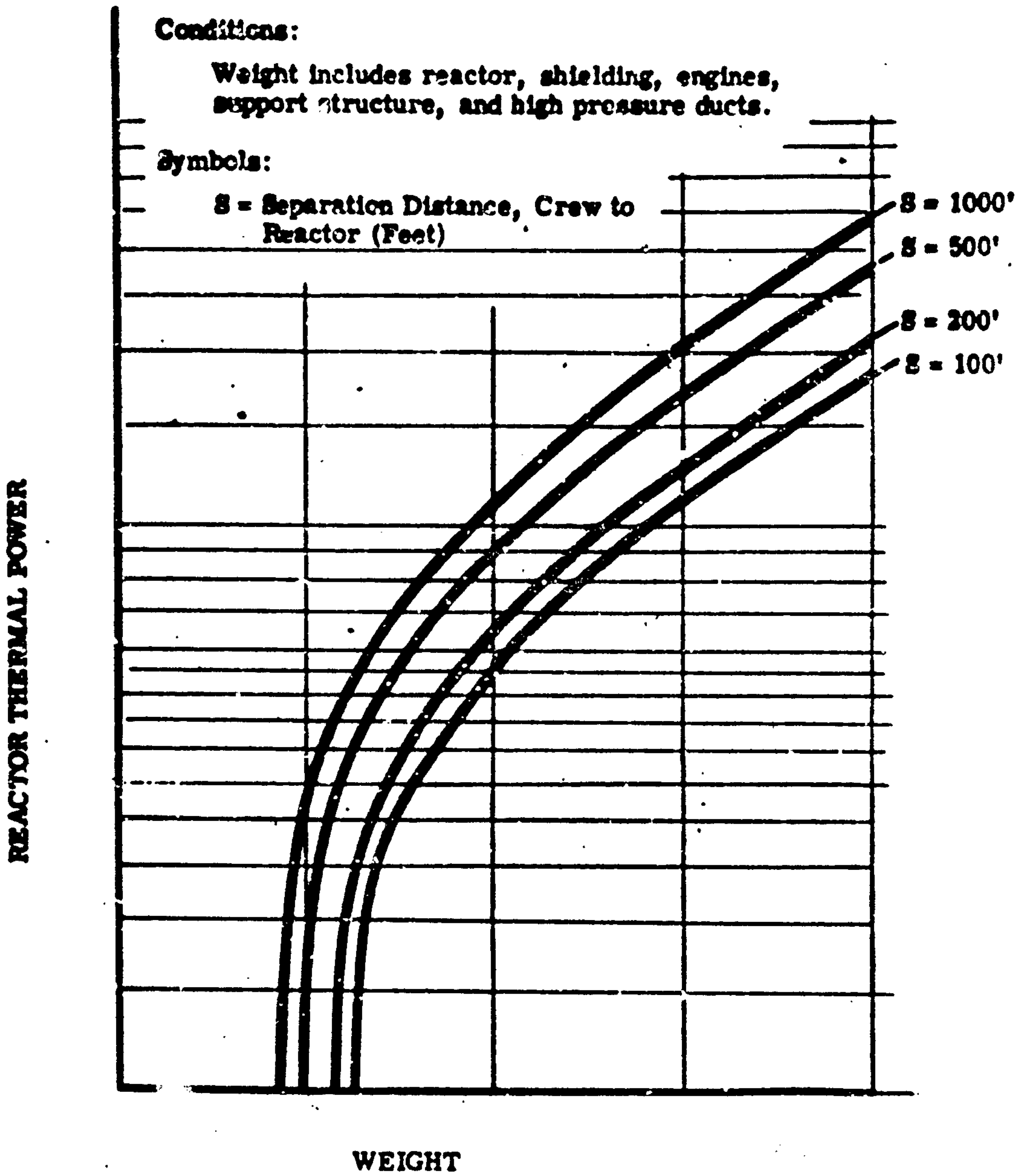

Figure E-7. Weight penalties for power increases when nuclear power plants are employed.

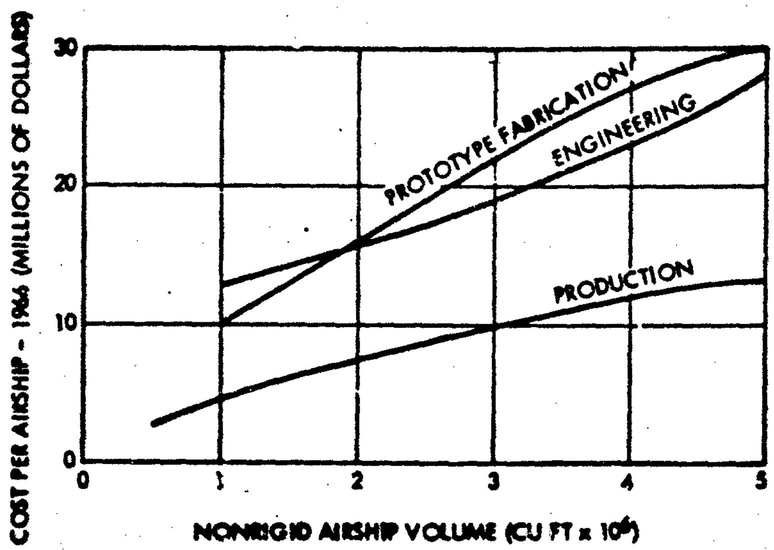

Figure E-8. Nonrigid airship cost estimates.

APPENDIX F

THE POTENTIAL OF HYPERSONIC VEHICLES

by

Mr. Charles H. McLellan
NASA Langley Research Center

With the recent death of the supersonic transport (SST) in Congress still fresh in our minds, it may seem ridiculous to talk about a hypersonic transport (HST). The HST, however, has the potential of overcoming many of the problems that were responsible for the position in which the SST found itself. Furthermore, we are not talking of building one in the near future; but rather of building the technology that would allow us to have an HST in the latterpart of this century, if all the attractive features we now see can be developed into an efficient system.

This developing of technology, of course, can be quite expensive. Fortunately, as shown in figure F-1, there are at least two other attractive systems that require essentially the same technology base and demonstration, and consequently could share much of the cost. The airbreathing launch vehicle, as the first stage of a second generation shuttle, could provide increased flexibility and a number of operational advantages over the current space shuttle. If our technology were ready, it is almost certain that the shuttle would use the airbreathing first stage. In the area of military aircraft, studies in the Air Force have shown that a greatly increased and flexible strike capability could be provided by the airbreathing aircraft.

In this paper the rest of the comments will be confined to the hypersonic transport with discussions of its attractive features and an indication of the status of the current technology. The hypersonic transport can provide a major reduction in flight time. This is particularly true if the airplane can be designed with a range on the order of 6,000 nautical miles so that it can serve the major long range routes without intermediate stops. In figure F-2 the range is shown as a function of Mach number. With the current technology and airplane in the 750,000-pound gross take-off weight class, the predictions indicate ranges of 4,000 nautical miles or less for JP fueled aircraft. This is slightly better than the advertized values for the current SST's and the Boeing SST. The low value for the Boeing SST is for the prototype aircraft while the upper points are for the growth production aircraft. In the supersonic range above about Mach 4, the use of superalloys would be required, and the heat capacity of the JP fuel is too small to cool the engine.

The use of hydrogen as the fuel allows the engine to be fuel cooled, as hydrogen has some 40 times the heat-sink capacity of JP fuel. Furthermore, hydrogen has nearly three times the energy per pound as JP fuel which provides large increases in range. Of course, this is not without penalties. The low density of the hydrogen requires large increases in the volume of the airplane with resulting increased drag and structural weight. In addition, the tanks must be insulated to prevent excessive hydrogen boil-off and cryopumping on the tank walls. System studies indicate that the range maximizes, at a Mach number between 6 and 7, at ranges of about 6,000 nautical miles. A large amount of uncertainty, of course, exists for aircraft so far in the future. The shaded area indicates our estimate of the uncertainty..

To be successful, an HST, of course, would also have to be economical. The current high cost of liquid hydrogen would price the HST out of competition, but the cost of hydrogen can be expected to be drastically reduced in the future, as shown in figure F-3. At the present time, liquid hydrogen costs about five times as much as hydrocarbon fuels per BTU. Increasing the production for the HST would greatly decrease the cost. The use of advanced power sources, such as fission or fusion power, the improvement of manufacturing techniques, and the sale of byproducts (O_2 in the electrolytic process) can be expected eventually to decrease the cost to the level of the present cost of hydrocarbon fuels. Because of the decrease in fossil fuel reserves, the cost can be expected to increase. The use of liquid hydrogen in the HST would free limited oil supplies for other uses.

Liquid hydrogen fuel when produced by electrolysis minimizes our ecological problems since the fuel would be made from water, and after combustion, would be returned to water. As shown in figure F-4, the HST would have no emission of CO_2, CO, solid particles, or unburned hydrocarbons. While it would exhaust more water per mile than an SST, it would have a greater payload for a given range with the result that there is little difference in pounds per passenger mile. While the possibility that the high altitude discharge of water would upset our ecology was used against the SST, nothing that we know of indicates this to be likely. However, before a fleet of HST's are ready to fly, either a better evaluation will have been obtained, or the hypothesis will have been forgotten.

Before leaving the use of hydrogen, there is another area I would like to discuss. Hydrogen has been labeled as a very dangerous fuel in many quarters; but, then, JP fuel is also a dangerous fuel, and we have been able to live with it. About 10 years ago, Arthur D. Little Company made a study of the relative hazards of liquid hydrogen and JP fuel. They have a very good motion picture on this subject. The general conclusions of their study are shown in figure F-5. They concluded that it was a well behaved fuel, and in some respects safer than JP fuel. As a matter of fact, the space program has been using liquid

hydrogen in the Centaur and in the upper stages of the Saturn booster, and no failures have been attributed to the hydrogen. In 1957, our Lewis Lab successfully flew a B-57 in which one engine was fueled with liquid hydrogen. Hydrogen fuel, therefore, appears to be a suitable fuel for use in an aircraft.

Earlier I mentioned that the HST would have to be economical. An important fact in this is to have as many routes open to the airplane as possible. The fact that the SST could not make supersonic flights over populated areas had a serious impact on its potential. As shown in figure F-6, the SST was designed to operate at almost the worst speed range from the sonic boom standpoint. As the speed is increased, the airplane flies at a higher altitude, and the pressures are spread over a bigger area of the earth with the result that the sonic boom pressures at ground level are greatly reduced.. The method used in these predictions has been checked with X-15 results at a Mach number of about 5. Although all sonic booms over land have been prohibited; eventually, some level of pressure will be allowed. For example, we are constantly exposed to levels of noise that are equivalent to about 1 to 1.25 psf, and we think nothing of it. Assuming this sonic boom level becomes acceptable, an HST would fly over land as shown in figure F-7.

The HST will still have sonic boom problems during acceleration and descent which would probably restrict takeoff and landings to coastal areas where the acceleration could be made over water. A flight from New York to Los Angeles would require about an hour and a half, while any other method would require 4 to 5 hours. Flights could be made from Los Angeles to Paris in about 2½ hours, or about ¼ that for the 747 or SST when allowance is made for one stop to refuel. Of course, the greatest gains would be on the long, trans-Pacific flights.

Most of these advantages for the HST are not strictly new since they are fundamental in nature. Why, then, are we becoming excited about them now? Technology has been slowly developing to the point where we can now see that these advantages can really be achieved. There are:

- Improved analytical and experimental approaches
- Six successful small, airbreathing, research engines
- Advanced H_2-cooled engine structures
- New, integrated engine concepts
- Hot structures and H_2 tankage being developed for shuttle
- Cooled structures concepts.

The Hypersonic Research Engine (HRE) built by Garrett for Langley is a light-weight (flight weight) engine. It is shown in figure F-8 mounted in the Langley, 8-foot high temperature structures tunnel, where it is now completing heat transfer and structural tests. It is still to be tested at our Lewis Center Plumbrook facility with combustion.

While test engines have been establishing the necessary technology and confidence, we have been looking at more-advanced concepts shown in figures F-9 and F-10. By integrating the engine and airframe, the whole bottom of the airplane becomes part of the engine, with the forebody providing part of the compression of the air and the aft part of the body forming the exit nozzle. In this concept the engine is divided into several small modules which can be largely developed and tested separately. By having a nearly square engine, the cooling requirements are drastically reduced, and some of the heat-sink capacity of the fuel can be used for other purposes, such as cooling the airframe.

Typical temperatures of a Mach 8 aircraft, in which no cooling is used other than radiation, is shown in figure F-11. As you can see, the exterior of the airplane would be red hot. In addition to the thermal deformation problem, a major problem would be to protect the aircraft's contents or interior. If the heat capacity of the fuel can be utilized to cool the airframe in the region of 200° to 500°, conventional materials can be used and the problem of protecting the interior is less severe. The coolant requirements are given in figure F-12. The coolant requirements are less than that available in the fuel as it flows to the engine. An analysis by Mr. J. V. Becker has shown that only a small fraction of the heat capacity is needed to cool the airframe and that both the engine and airframe can be cooled up to about $M = 9$.

Bell aircraft, under contract, has been examining systems to cool the airframe, and an attractive one is shown schematically in figure F-13. A secondary coolant is pumped in a closed loop through integral passages in the skin and through a heat exchanger where it gives up its heat to the fuel on its way to the engine. Localized areas may require special cooling such as the slot cooling of a window shown in figure F-14. Both experimental results and theory shown that slot cooling is an effective cooling system at hypersonic speeds.

Although there are problems in applying cooling systems to hypersonic aircraft, particularly in the area of developing and providing the necessary reliability, there are many advantages, three of which are:

- Use of conventional materials
- Greater aerodynamic design freedom
- Larger potential increase in payload
  - Reduction in empty weight

- Reduction in drag

- Increase in specific impulse.

The studies have indicated that very substantial savings can be made in the structural weight by the use of conventional materials at the low temperatures. Since the cooled aircraft will be nearly free of thermal deformations, and can have smaller leading edges than can be cooled by radiation, the total drag will be reduced. These studies have shown that the combination can nearly double the payload capability of a long range version of the HST.

Using the cooled structure, our version of the HST might look like figure F-15. It would have a structural surface with windows very similar to that of current aircraft.

Before such an aircraft can become a reality, some form of flight demonstration will be required. The objectives of such a demonstrator aircraft are:

- Provide focus and stimulation

- Demonstrate hydrogen-fueled aircraft

  - Airbreathing propulsion

  - Long-lived structural designs

  - Operational aspects

- Provide flight research to supplement research in ground-based facilities.

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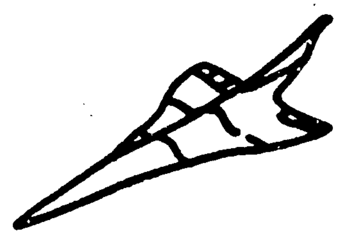
TRANSPORT

SHORT TRAVEL TIME
LONG RANGE
LOW SONIC BOOM
LOW POLLUTION
FOSSIL FUEL CONSERVATION



AIRBREATHING LAUNCH VEHICLE

AIRPLANE-TYPE TAKEOFF
SAFE ABORT
OFFSET ORBITS
OPERATIONAL FLEXIBILITY
ECONOMICALLY COMPETITIVE

MILITARY AIRCRAFT

LONG RANGE
HIGH SURVIVABILITY
RECALL CAPABILITY
RECONNAISSANCE CAPABILITY

Figure F-1. Three potential uses for a hypersonic aircraft in the 1990's.

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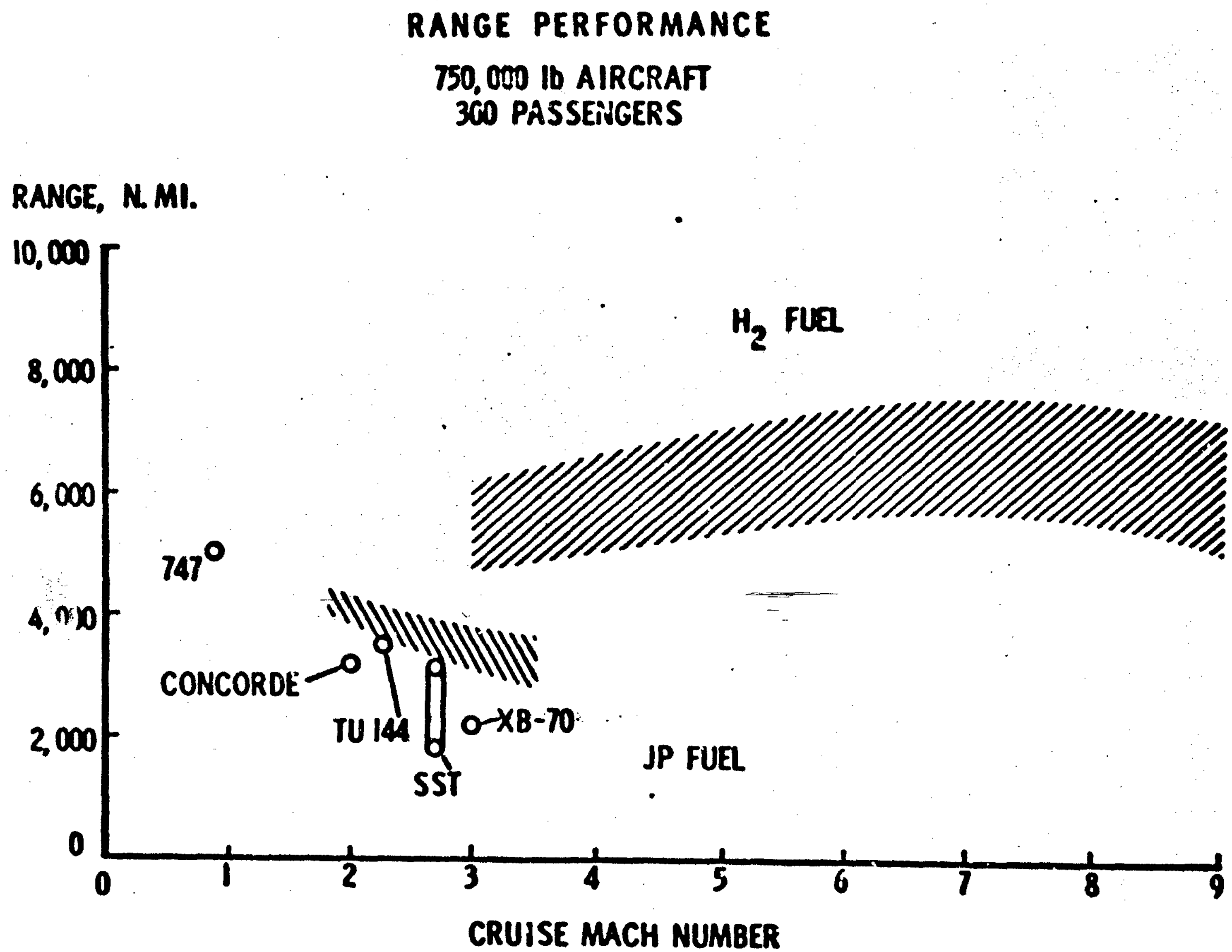

Figure F-2. Comparisons of range and speed for two fuel systems.

RELATIVE COST OF LIQUID HYDROGEN AND FOSSIL FUEL

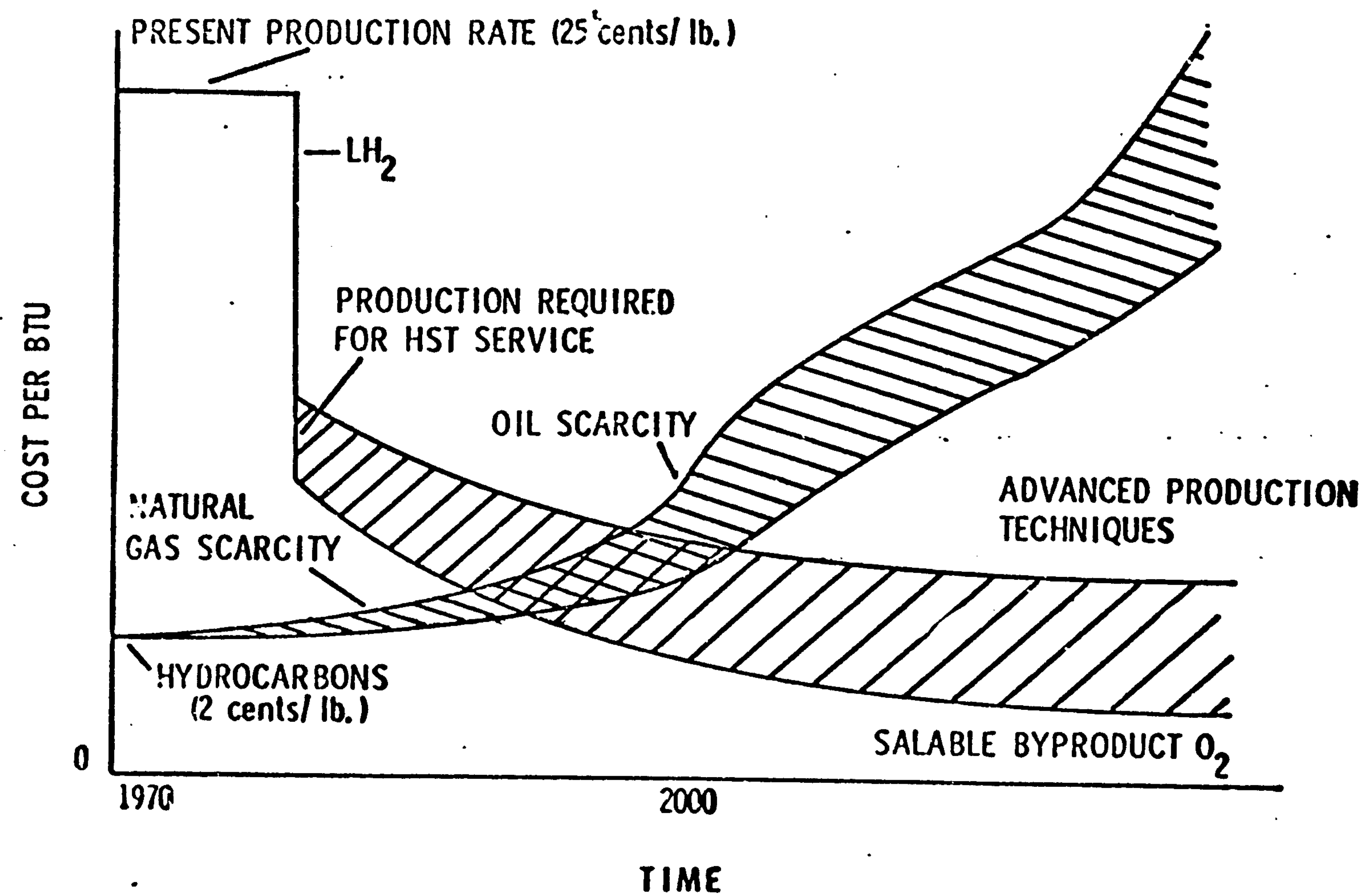

Figure F-3. Relative costs of hydrocarbon and liquid-hydrogen fuels.

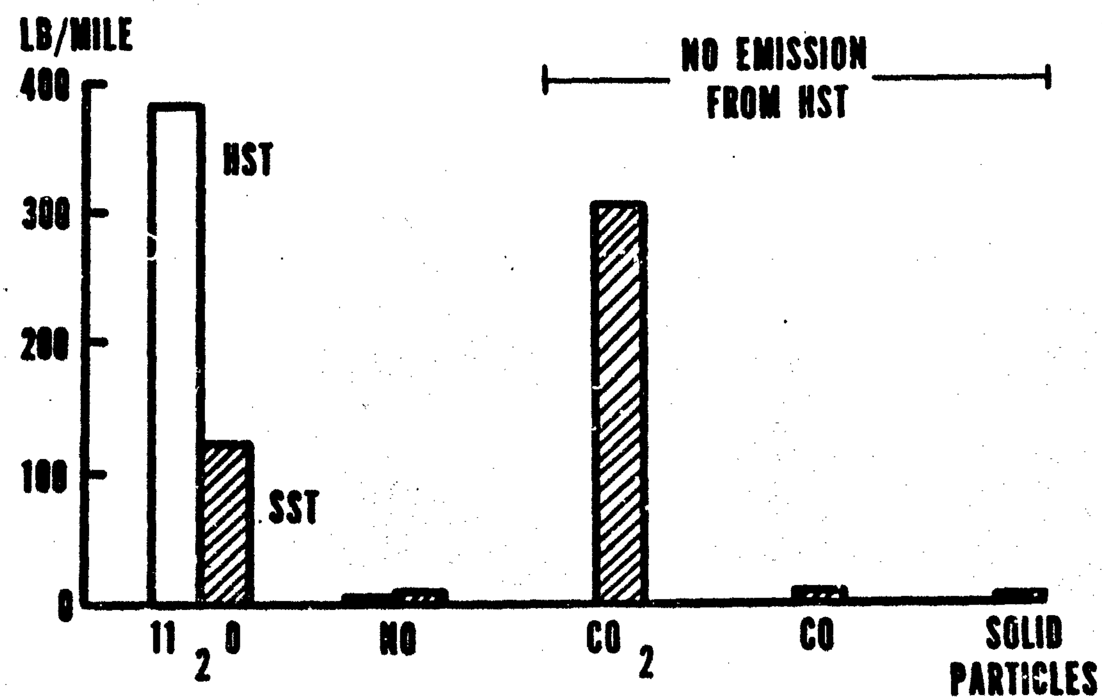

Figure F-4. Environment emissions at cruising speeds.

RELATIVE HAZARDS OF LIQUID HYDROGEN FUEL

DETONATION OF SPILLED FUEL HIGHLY UNLIKELY.

RAPID EVAPORATION (1/20 TO 1/50 TIME REQUIRED FOR HYDROCARBON WHEN FLAME IS PRESENT).

LOW HEAT RADIATION.

NO SMOKE TO CAUSE ASPHYXIATION.

Figure F-5. Hazards of use of liquid-hydrogen fuel relative to JP fuel.

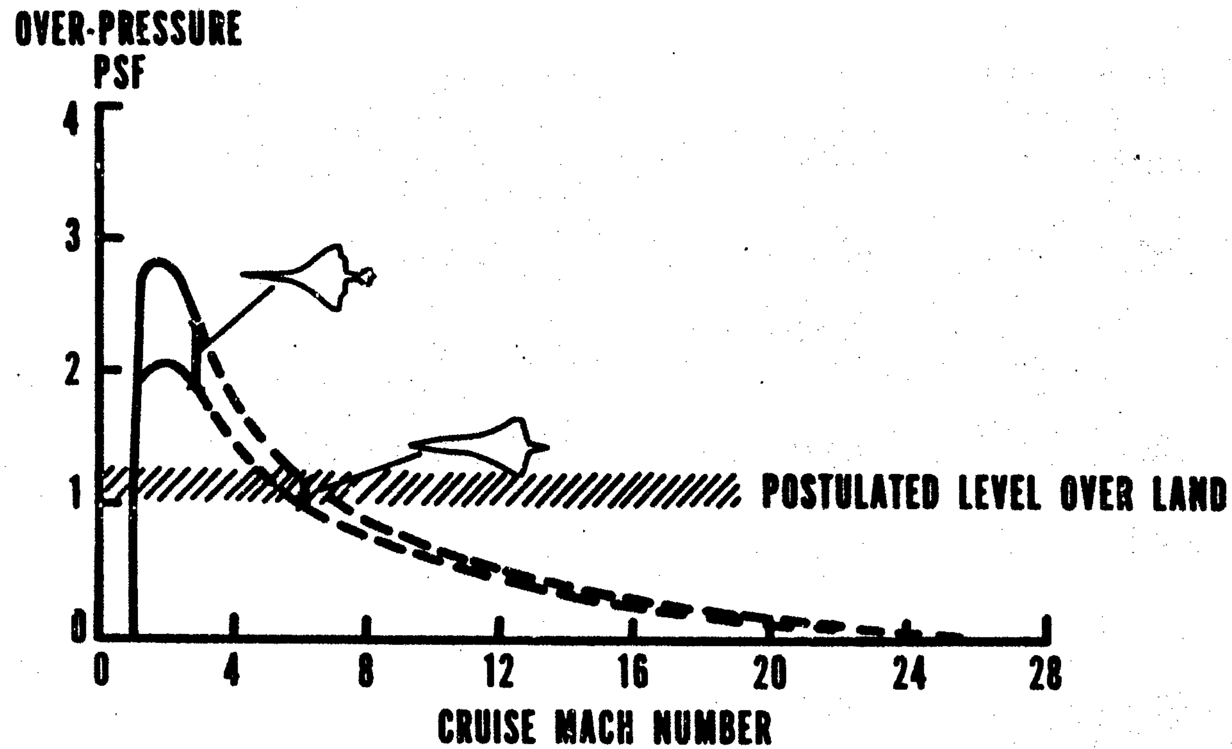

Figure F-6. Sonic boom comparisons for increasing speeds.

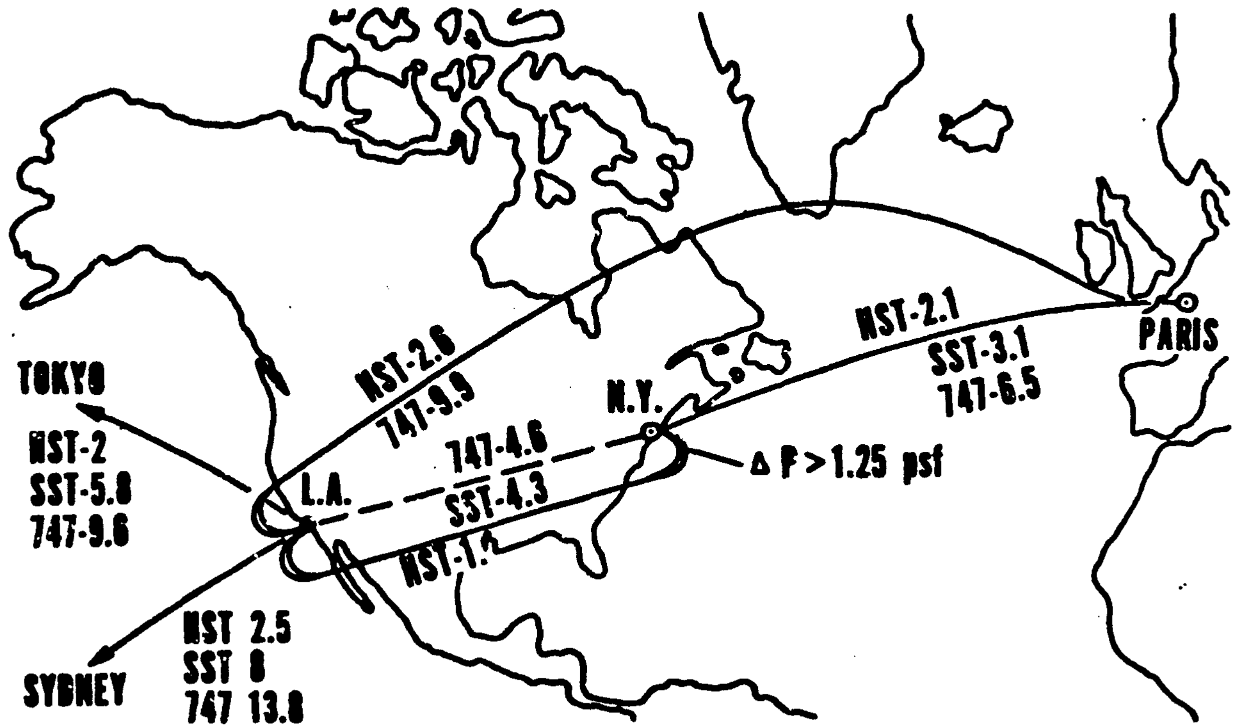

Figure F-7. One-way travel time comparisons (hours).

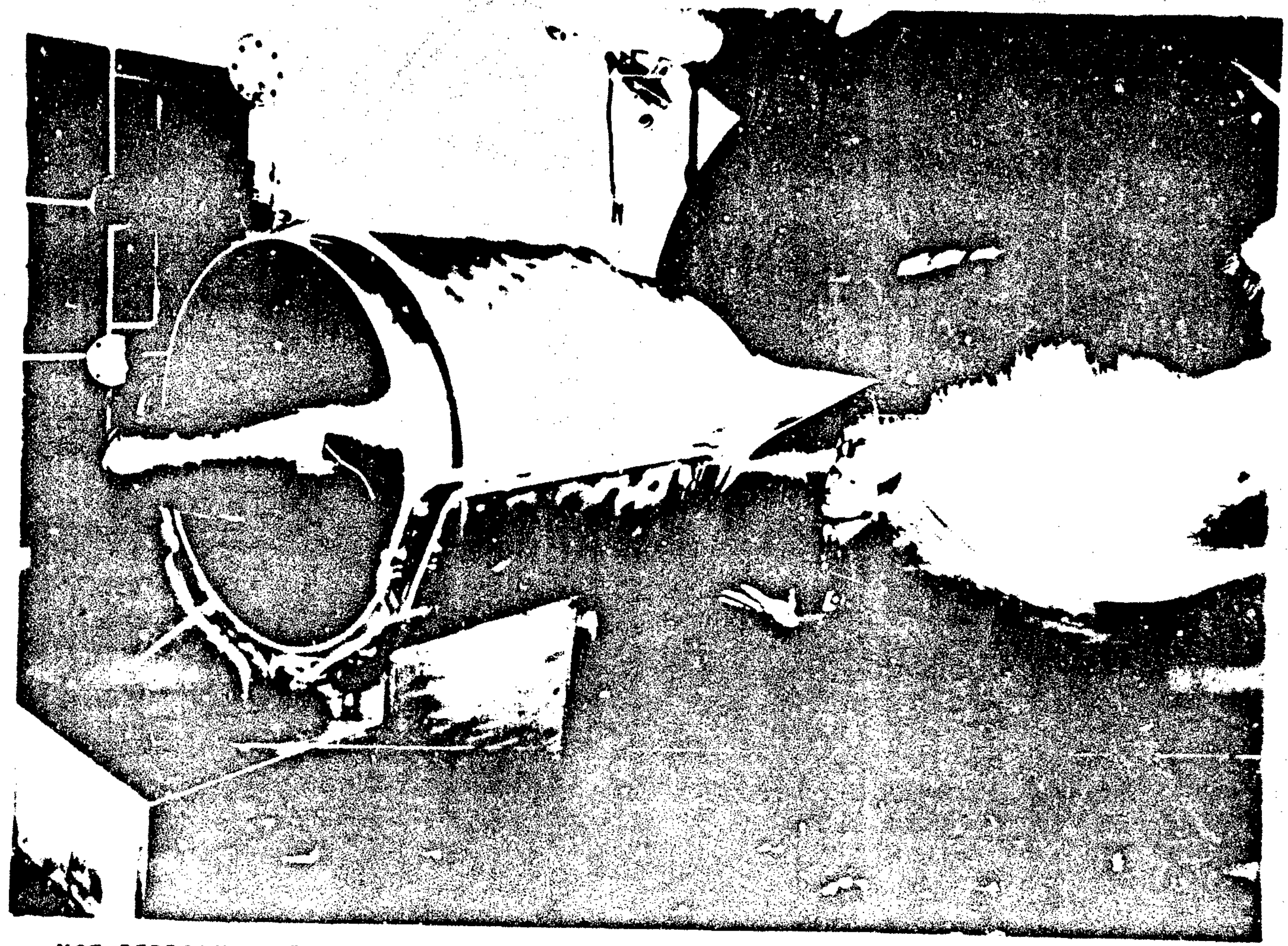

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Figure F-8. Hypersonic research engine mounted in the Langley temperature structures tunnel.

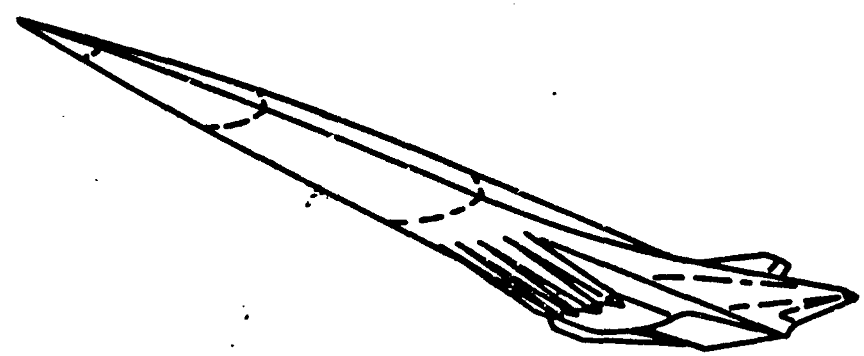

Figure F-9. Integration of engine and airframe in an advanced concept.

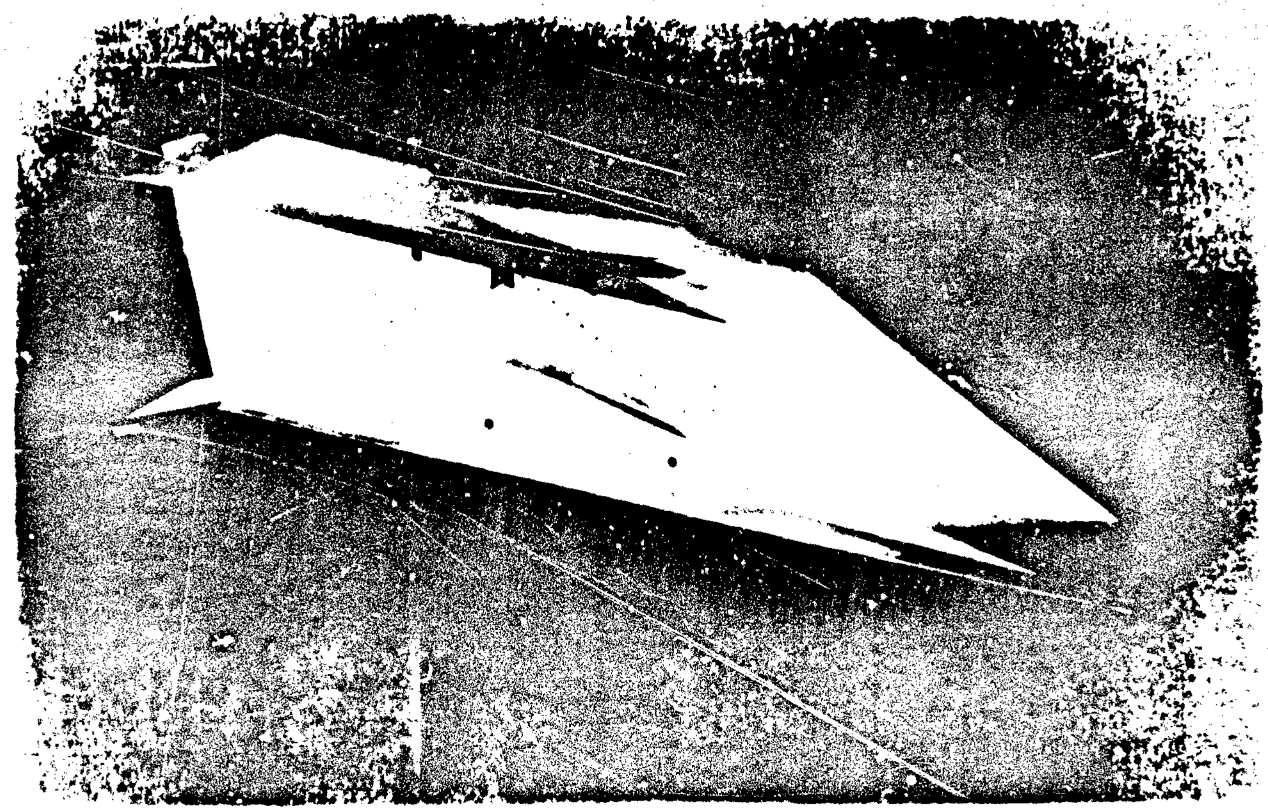

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Figure F-10. Test engine for advanced concept shown in figure F-9.

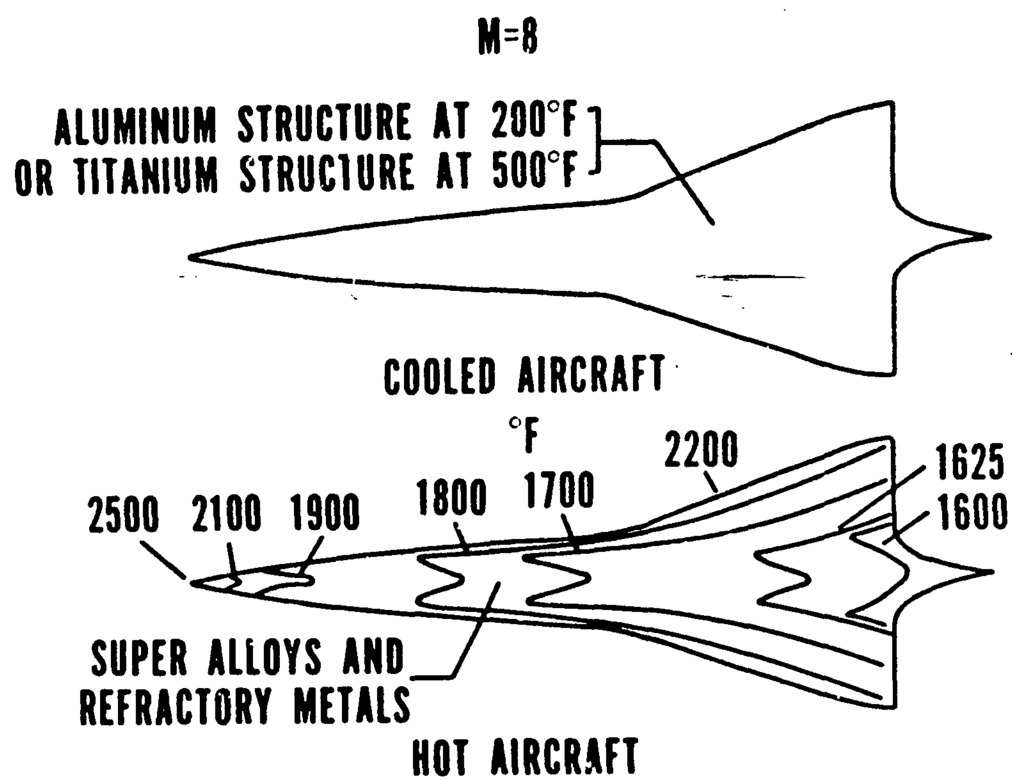

Figure F-11. Typical hypersonic aircraft temperatures.

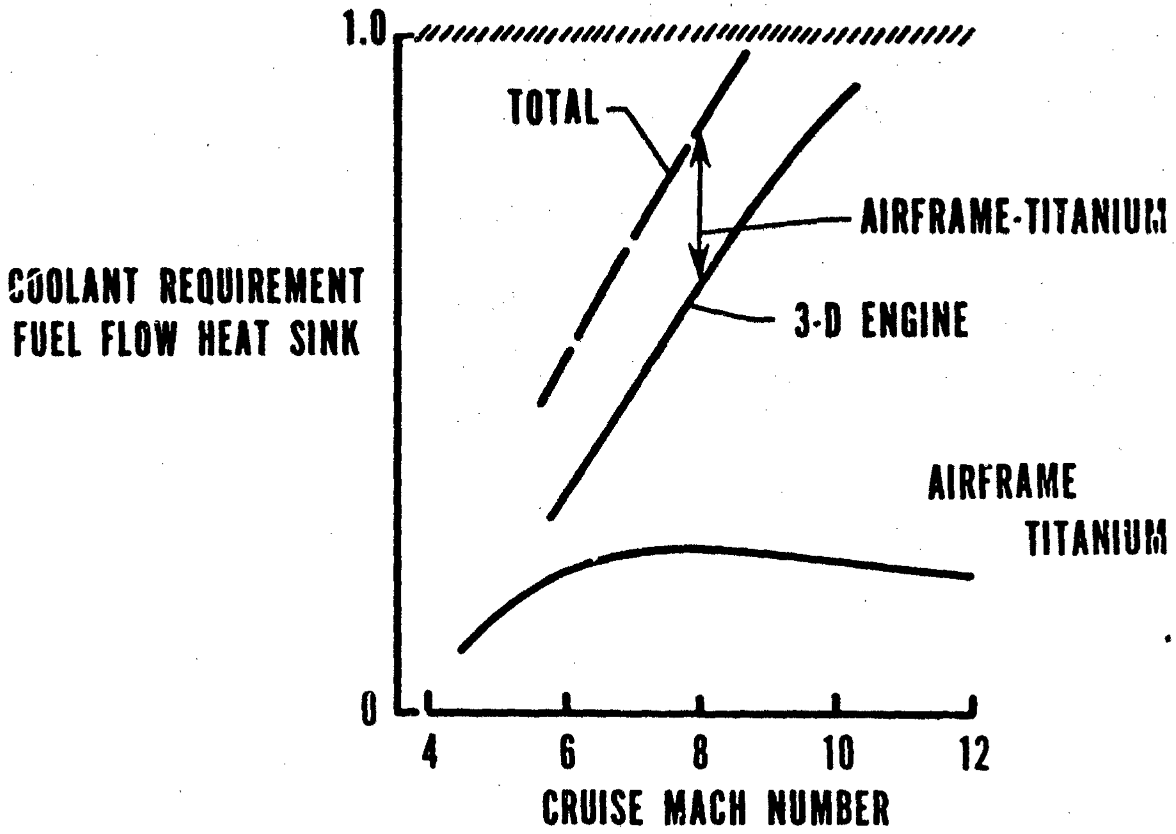

Figure F-12. Hypersonic airplane coolant requirements.

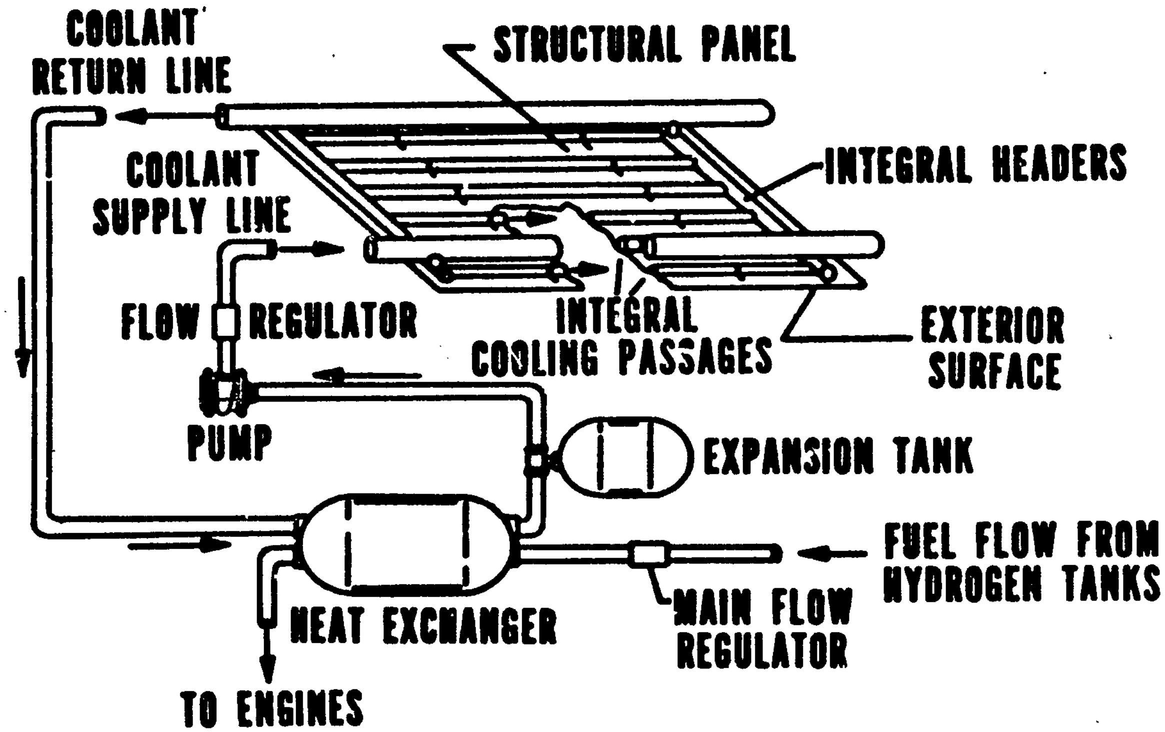

Figure F-13. Liquid-convective cooling system schematic.

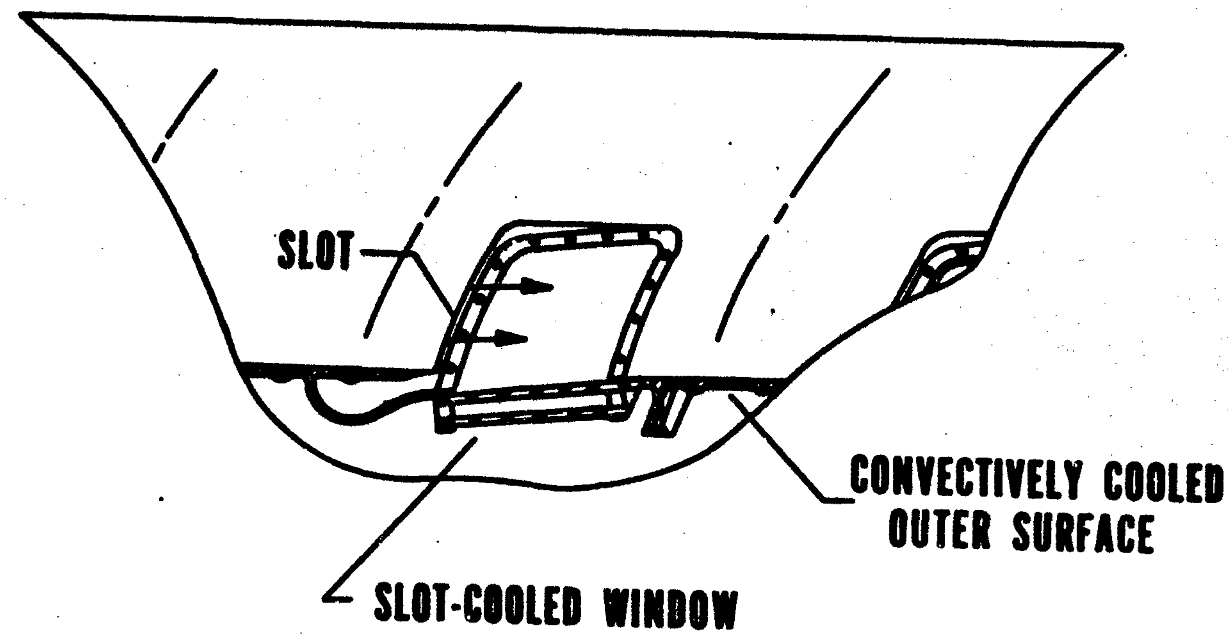

Figure F-14. Slot-cooled window schematic.

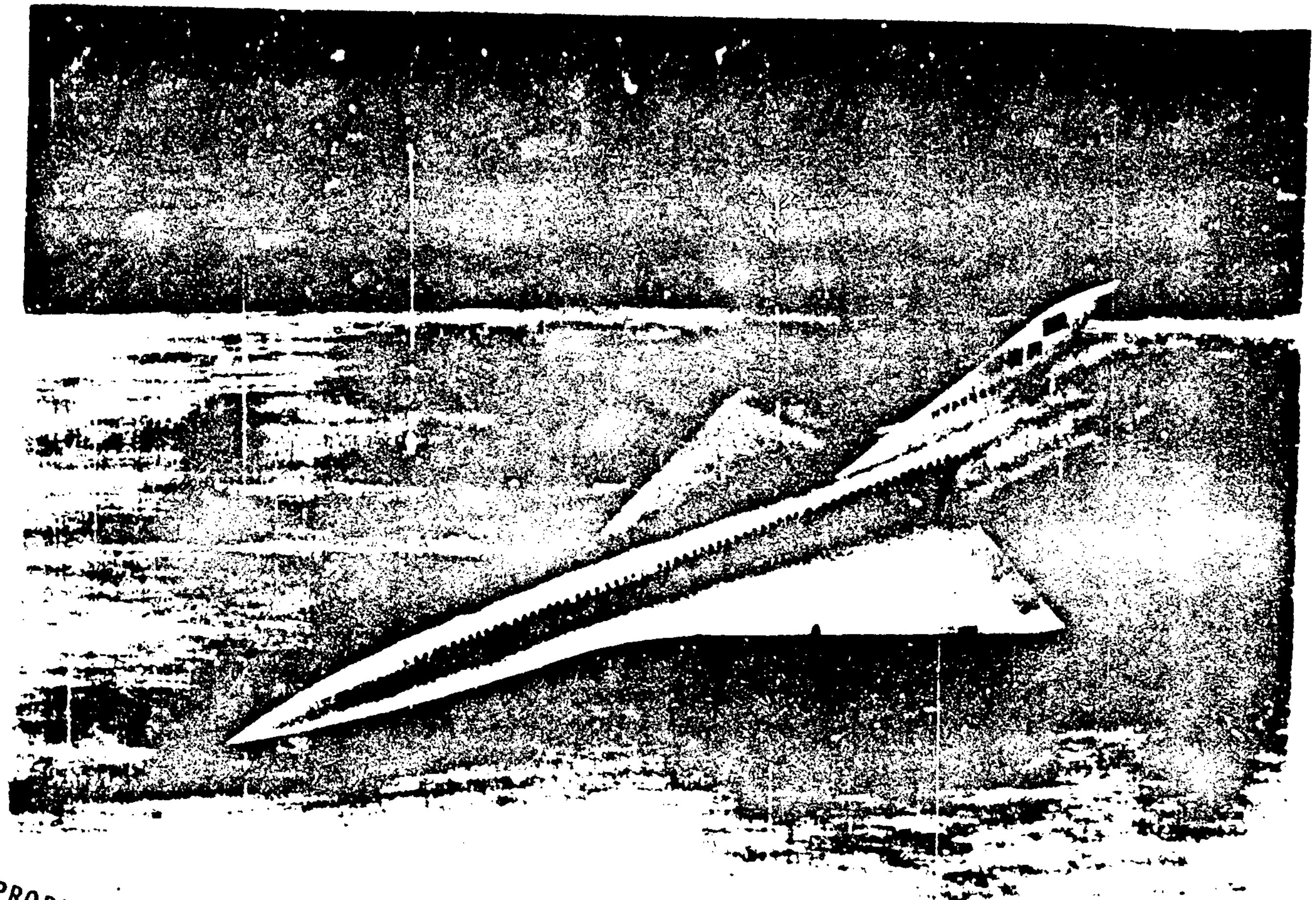

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Figure F-15. Artist's concept of a hypersonic transport.

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APPENDIX G

STATUS OF VTOL AND STOL TRANSPORT AIRCRAFT DEVELOPMENT

by

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SUMMARY

The helicopter which has been operational for well over 20 years has shown us the utility of VTOL performance. We have experimented with many other types of VTOL aircraft. Our problem is probably having too many ways of achieving a VTOL capability rather than having too few. If we have learned anything it is that if we put in enough power and have the right kind of control we can fly anything. The basic question is, rather, how do you match the vehicle concept with the job you want to do; and that is infinitely more difficult to decide than it is to build an airplane and to prove that it works.

We have experimented with some 20-odd different vehicles. What I propose to do is to review some figures describing relative performance of some of these concepts. Then I will take a few examples of the various types and discuss briefly where they stand now in development.

Figure G-1 compares power requirements to cruise-speed capabilities for several aircraft types. Speed is the design cruising speed. Specific power is the power used at cruising, divided by the weight times the velocity. The figure gives an idea of the relative effectiveness and efficiency of the vehicles. We see the conventional jet transports in the lower right hand corner of the chart with speed of the order of 500 knots and the lowest specific power, about .05. Specific power is roughly equivalent to the inverse of the lift/drag ratio. In other words, conventional jet transports have an L/D of 16 to 20. That includes both military and civil transports.

In the upper left corner of the figure we have the other end of the spectrum, the pure helicopter with the effective L/D of the order of 4. In between, are a lot of other VTOL types. We see that a compound helicopter gives us an improvement in both speed and efficiency, but we are still limited to low speeds. The area marked low-wing-loading STOL includes vehicles like the Twin Otter and Caribou. These are quite a bit cheaper than the VTOL's but are still limited to low speeds.

Now, I understand that you are interested primarily in the longer-range missions, so the rest of my discussion relates to those vehicles that have speeds in the 300 mile an hour and up category. In figure G-1, the tilt-rotor shows less efficiency than some of the others because it has a huge rotor turning at low speeds. The deflected slipstream STOL and the tilt-wing STOL are in the speed range of about 400 knots. Only the jet-flap STOL and the lift-fan VTOL's get into the 500-knot speed range.

Figure G-2 presents a comparison of the hovering characteristics of the VTOL types. The fuel required for hover is presented as a function of cruise speeds. We see that all the rotorcraft get by with very little fuel. The pure lift jet, however, takes a lot of fuel. For high-subsonic performance, fuel consumption considerations drive our thinking in the direction of lift fans. The other thing that is driving our work in the direction of the lift fan and the turbofan as opposed to the pure jet is the noise problem. Low jet velocities and low tip speeds are required to keep the noise down.

The tilt-wing concept is the most highly developed VTOL type (other than the helicopter). Control, when the wing is in the vertical position, is achieved by differential blade pitch of the propeller for roll control and differential flap deflection for yaw control. A tail fan provides pitch control. Three designs have been built and tested; the Vertol VZ-2, the Vought XC-142, and the Candian CL-84 (figure G-3) which is the most recent and is still in development. Five copies of the XC-142 were built and used extensively in both engineering and operational type flight tests. While highly successful in almost all respects it was noisy and experienced an adverse ground effect in STOL landings between wing incidences of about 35 and 75 degrees. The CL-84 is much quieter because it uses lower tip speeds and does not experience the adverse ground effect because the wing is higher and the lateral/directional control system is more powerful.

Moving up in speed, the German Dornier DO-31 (figure G-4) uses jet lift to achieve VTOL performance. There are four pure jet lift engines in each wingtip pod and two cruise engines with swiveling nozzles inboard. All engines are used for vertical takeoff and landing. Roll control is by means of differential throttling of the pod engines, and yaw control by vectoring the nozzles. Pitch control is by bleeding air to nozzles in the nose or tail. The DO-31 has an attitude command-and-control system that apparently makes it easy to fly. The biggest problem with the concept is its noise level and high fuel consumption rate.

Lift-fan configurations (figure G-5) offer potential for reducing noise and fuel consumption. However, the fans must not be placed in the wing because they compromise both the wing and the fan. The more likely configurations involve fuselage mounting or placing them in pods out on the wing.

To this point I have discussed VTOL. The balance of the paper will deal with the short-takeoff-and-landing aircraft (STOL). Figure G-6 shows one factor relative to the question of STOL performance, the thrust required as a function of speed. At the top of the figure it is shown that if most of the lift is carried on individual units (jets or fans) the wing is not doing much lifting and the power required is high through most of the low-speed range. If we can spread the propulsion along the wing and make that wing work for use at a higher lift coefficient, we can drastically reduce the power required in the STOL approach speed range of 60-80 knots. This is the thrust-weight required to maintain flight. Additional power must, of course, be installed to take care of the engine-out problem and the temperature-altitude conditions of the takeoff and landing site.

Another factor in STOL performance is shown in figure G-7. In this figure, speed and approximate field length are related to wing loading. There are several important factors shown here. The curved lines indicate a constant lift coefficient. For conventional jet transports, such as the 727, maximum lift coefficients about 2.7 are available; but safety reasons and operation margins reduce the actual operating lift coefficient to about 1.5 to 1.8. Many of the so-called STOL airplanes that we have today operated in the same range. They have lower approach speeds simply because of the lower wing loading in which they operate. STOL research today is directed at getting their kind of takeoff and landing performance at the higher wing loadings appropriate to high cruising speeds.

The shading on the lift coefficient 4 line labeled "current propeller STOL" is for the French Breguet 941 deflected slipstream class of airplane (figure G-8), the first true power-lift STOL airplane that we have had. This concept uses large flaps to deflect the propeller slipstreams downward to produce high lifts at low speeds. The concept is highly developed and the technology is essentially "on the shelf." The primary drawback is the speed limitations of propeller drive aircraft. (See figure G-1.)

In order to achieve higher cruise speeds several types of turbofan STOL configuration are receiving attention now. The externally blown flap concept (figure G-9) uses high-bypass-ratio engines blowing through the flap system to generate the high lift. Actually this concept was originated in the early 50's; but all that was available then were the pure-jet engines which would put the flap in an extreme environment in terms of temperature and dynamic pressure. The advent of high-bypass engines like those on the 747 or the C5 with lower temperature, larger diameter, and slower exhausts brought this concept back into prominence. An obvious problem with this type was that of control following engine failure. Wind-tunnel tests have shown that this can be solved by placing the engines inboard, putting them up fairly high, and using a powerful lateral control system.

An alternate approach to the externally blow flap would be to take air from special engines, duct it across the span, and blow it over the flap system. One method is the old, conventional jet flap. In this the air is simply blown like boundary layar control over the upper surface. This appears to have advantages from the noise point of view. Another approach is the "augmentor wing" in which the jet sheet is not attached to the flap surface. It blows through the gap formed by two elements of the flap so that it operates as a jet pump to suck in extra air for augmented performance. A research vehicle of the augmented-wing type is presently being built by Boeing for the NASA-Ames Research Center (figure G-10). This is a modification of a DeHaviland Buffalo and will be flying in 1972.

At this point in time, the externally blown flap appears to be the simplest and can use conventional engines. The internal-flow type appears to be more efficient but requires special engines to get the air at the right quality and pressure for the flap system. The upper-surface-blown aircraft type -- the conventional jet flap -- at this point appears to be the quietest.

In conclusion, the technology for the propeller driven VTOL and STOL concepts is available. The externally blown flap type, we think, may be the more promising in the near term for the turbofan powered STOL because of the engine situation. The lift fan appears to be the high performance VTOL type of the 80's.

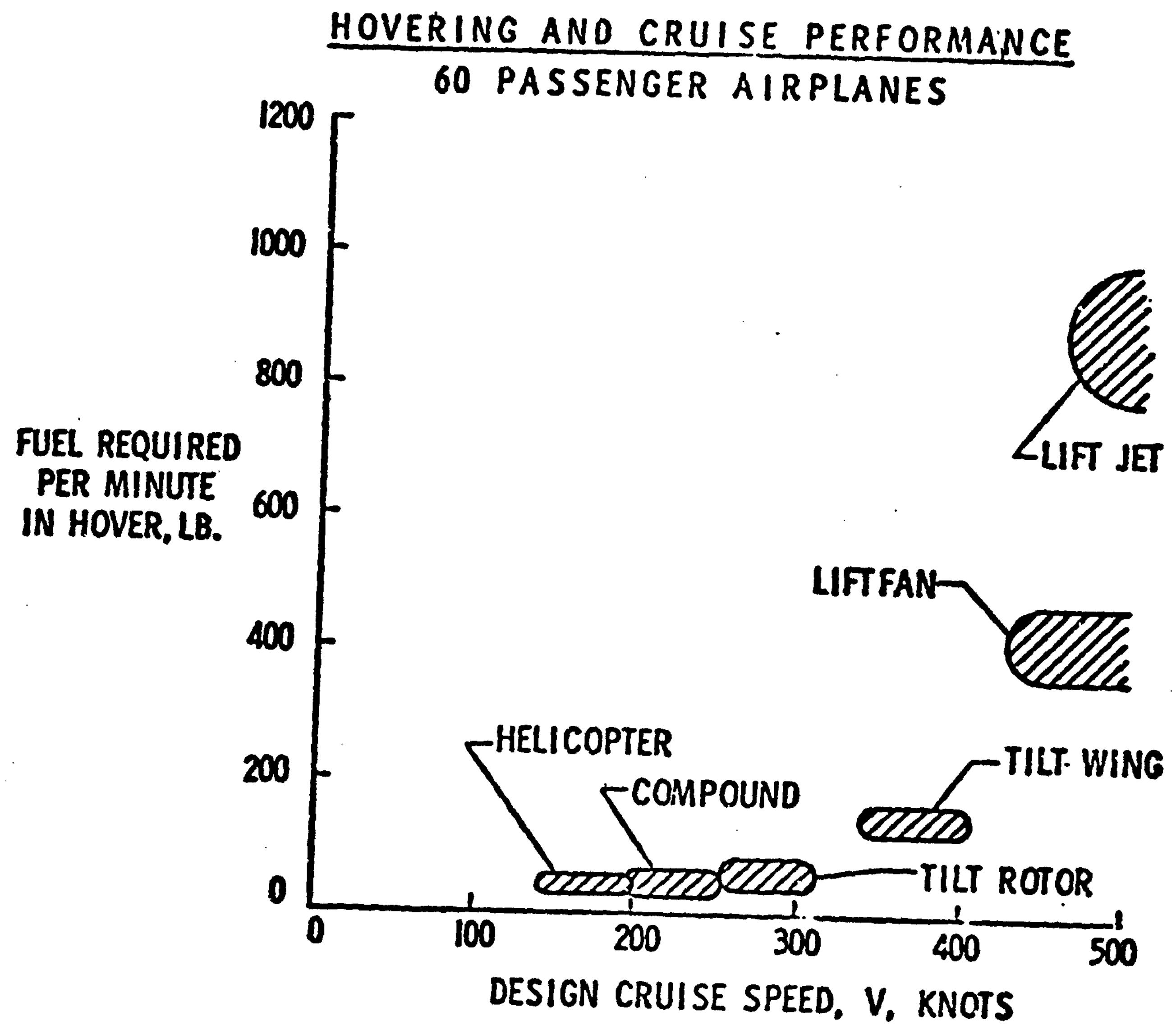

Figure G-2. Hover performances and cruising speeds for alternative aircraft designs.

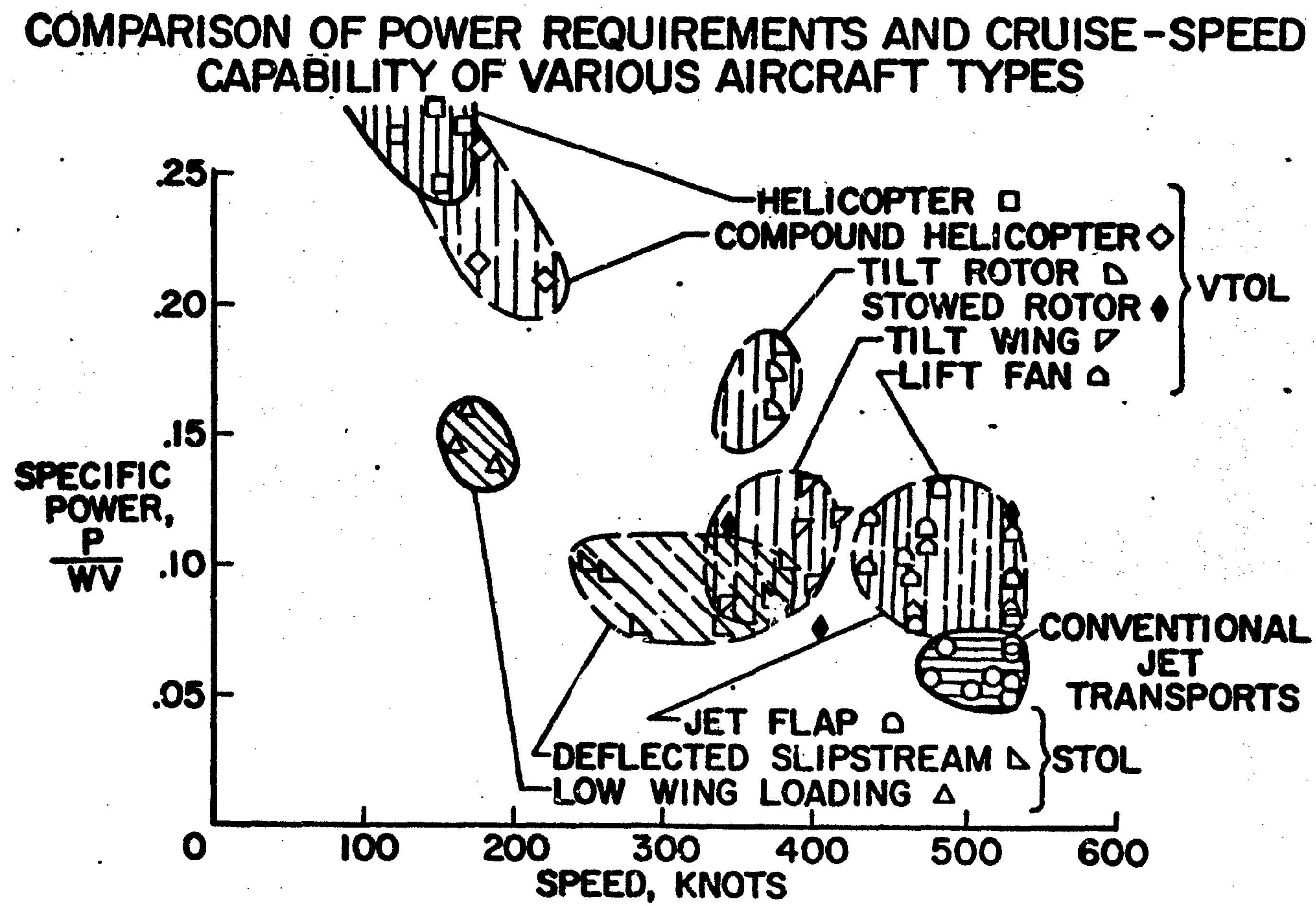

Figure G-1. Comparison of power requirements and cruise speed for several aircraft alternatives.

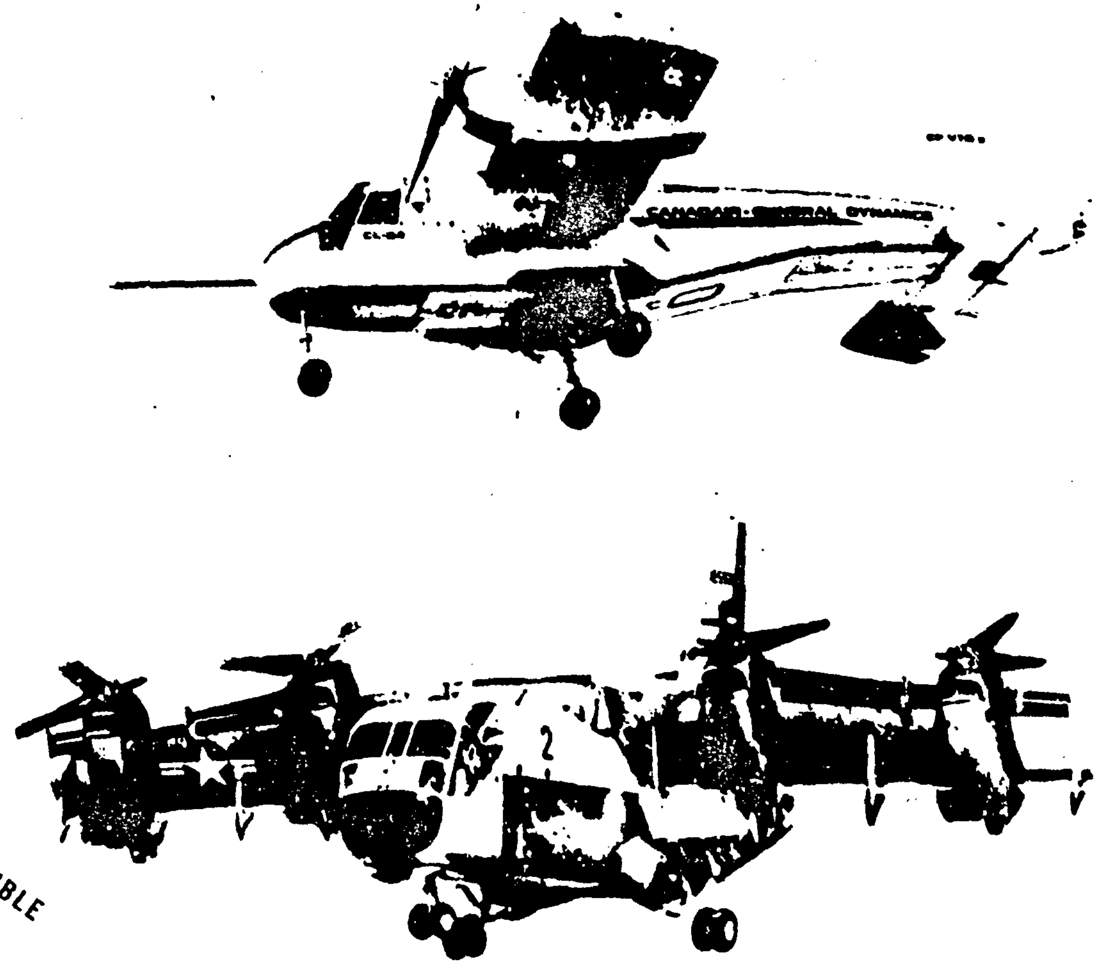

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Figure G-3. Canadair CL-84 and XC-142A tilt-wing airplanes.

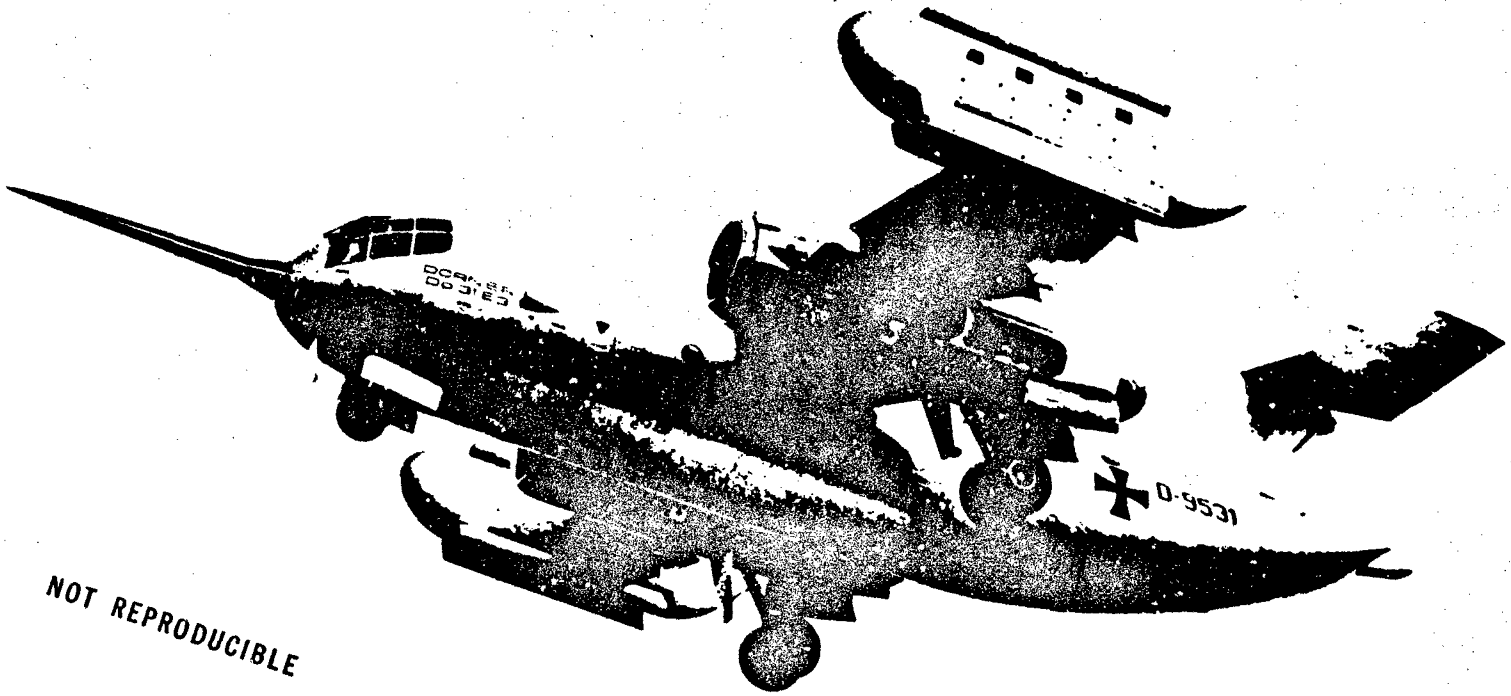

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Figure G-4. Doriner DO-31 lift-jet V/STOL aircraft.

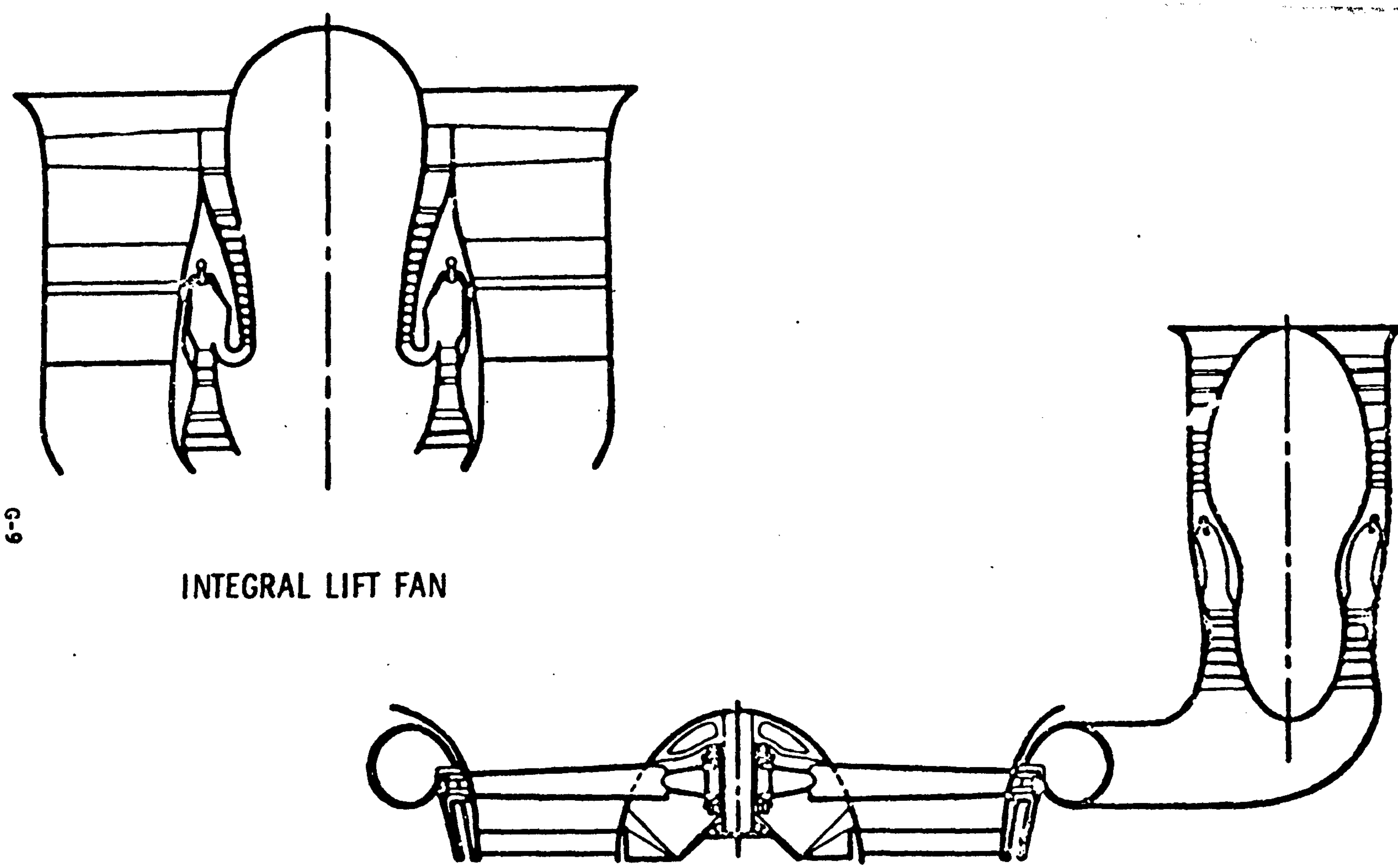

Figure G-5. Types of lift fans.

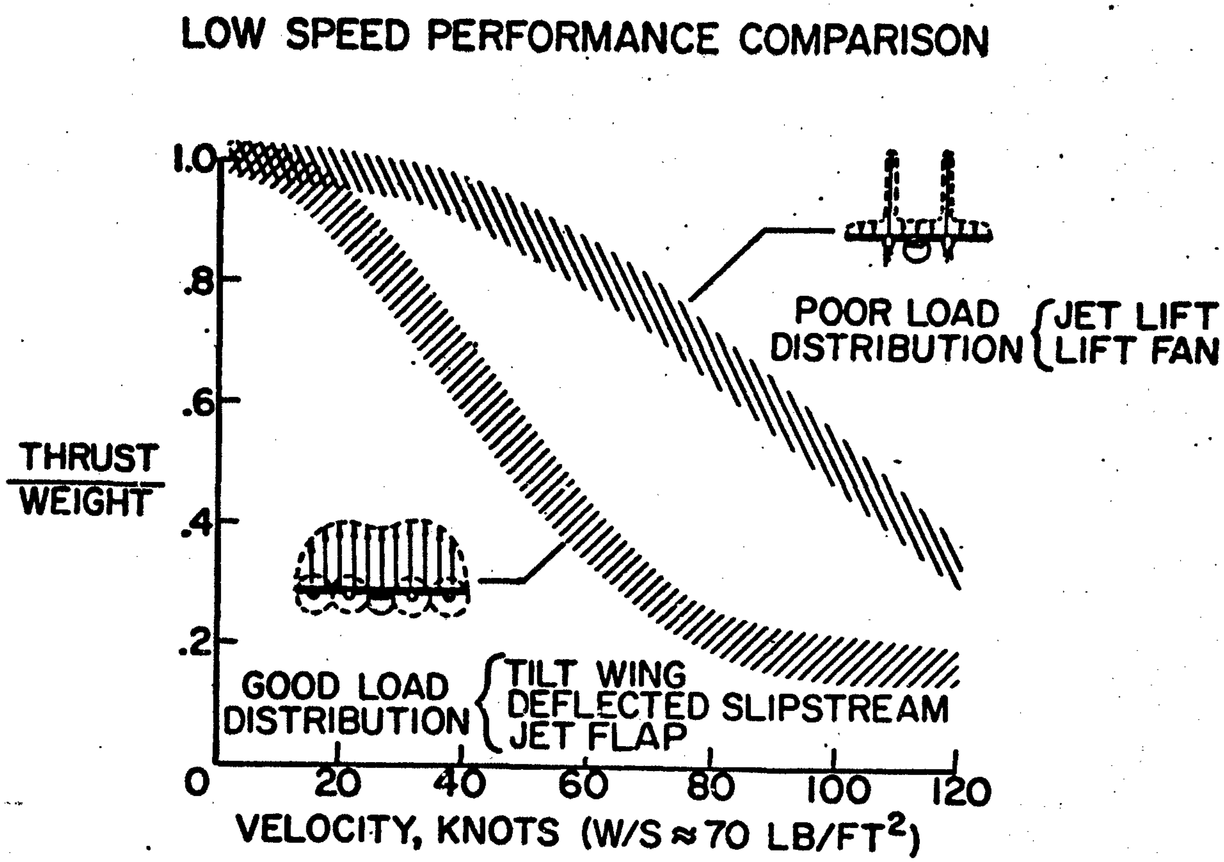

Figure G-6. The effect of wing-load distribution on performance.

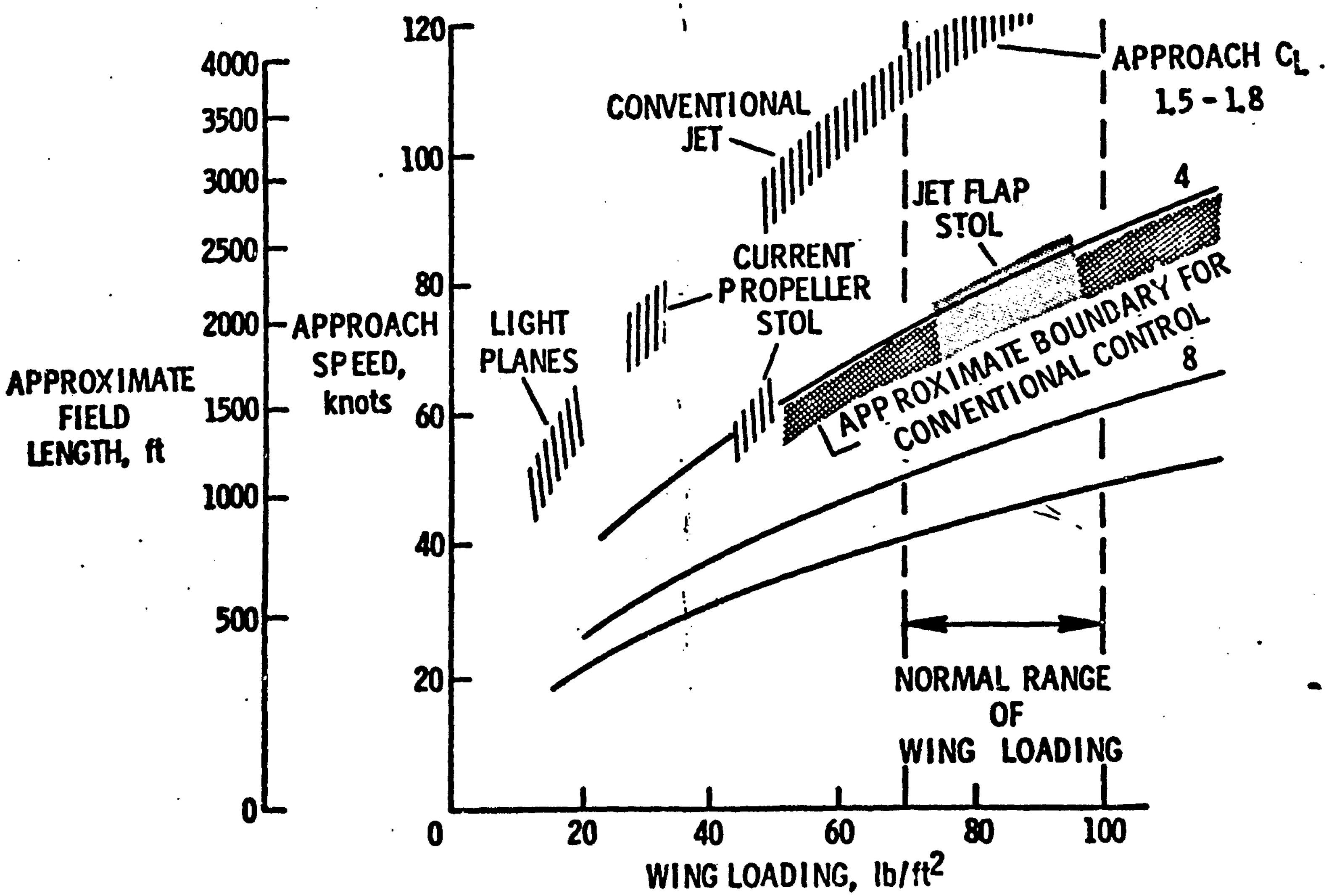

Figure G-7. Field length considerations.

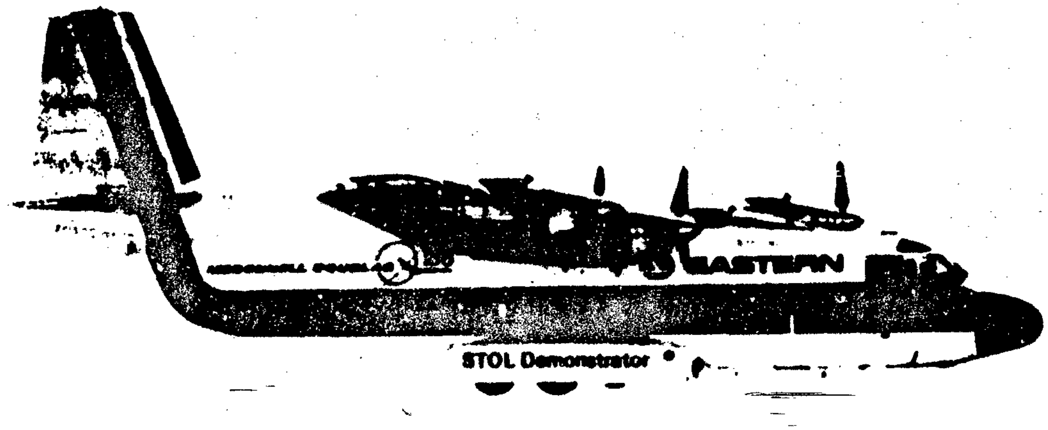

Figure G-8. Breguet-McDonnell Douglas deflected-slipstream STOL

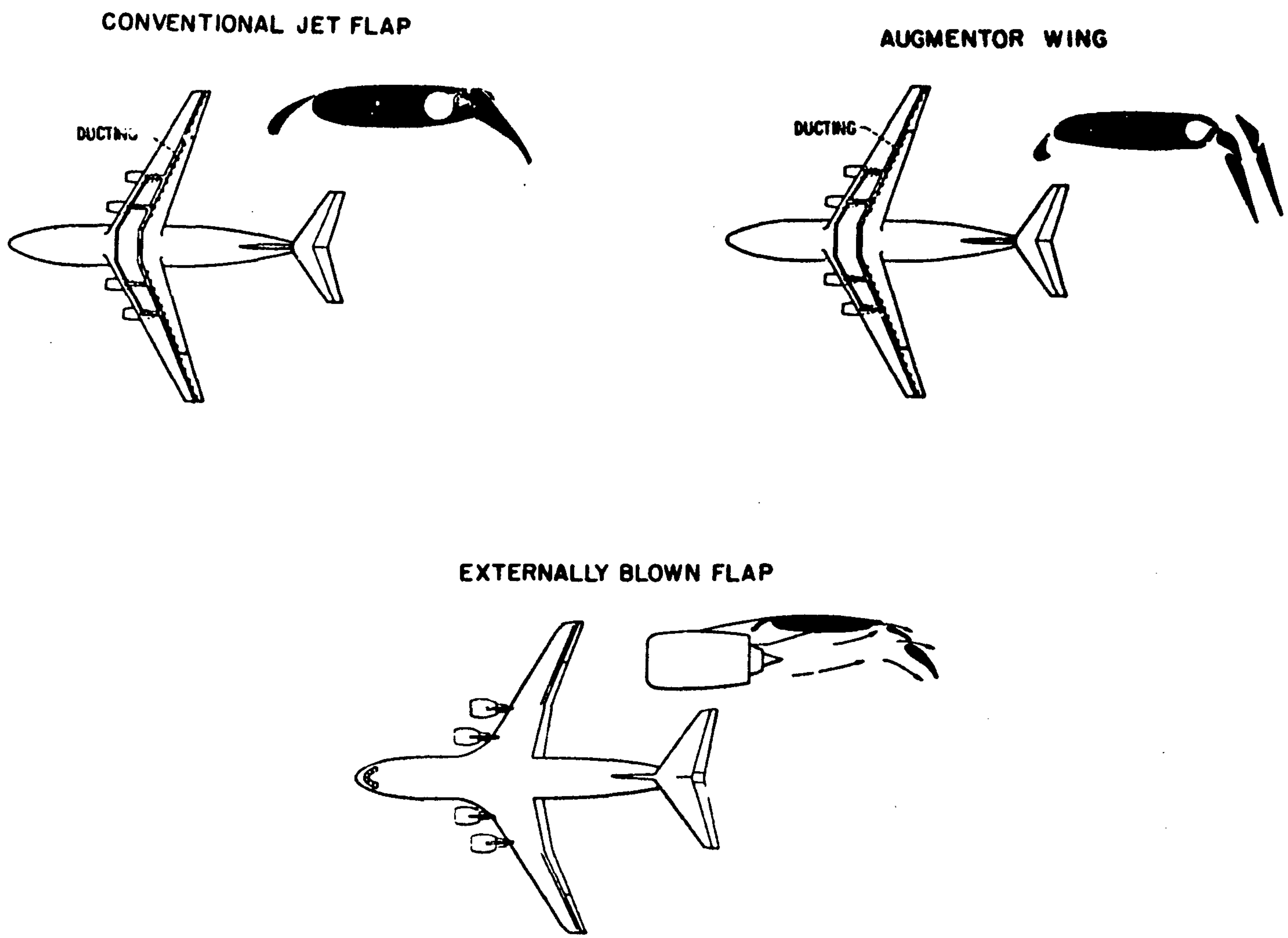

Figure G-9. STOL high-lift systems.

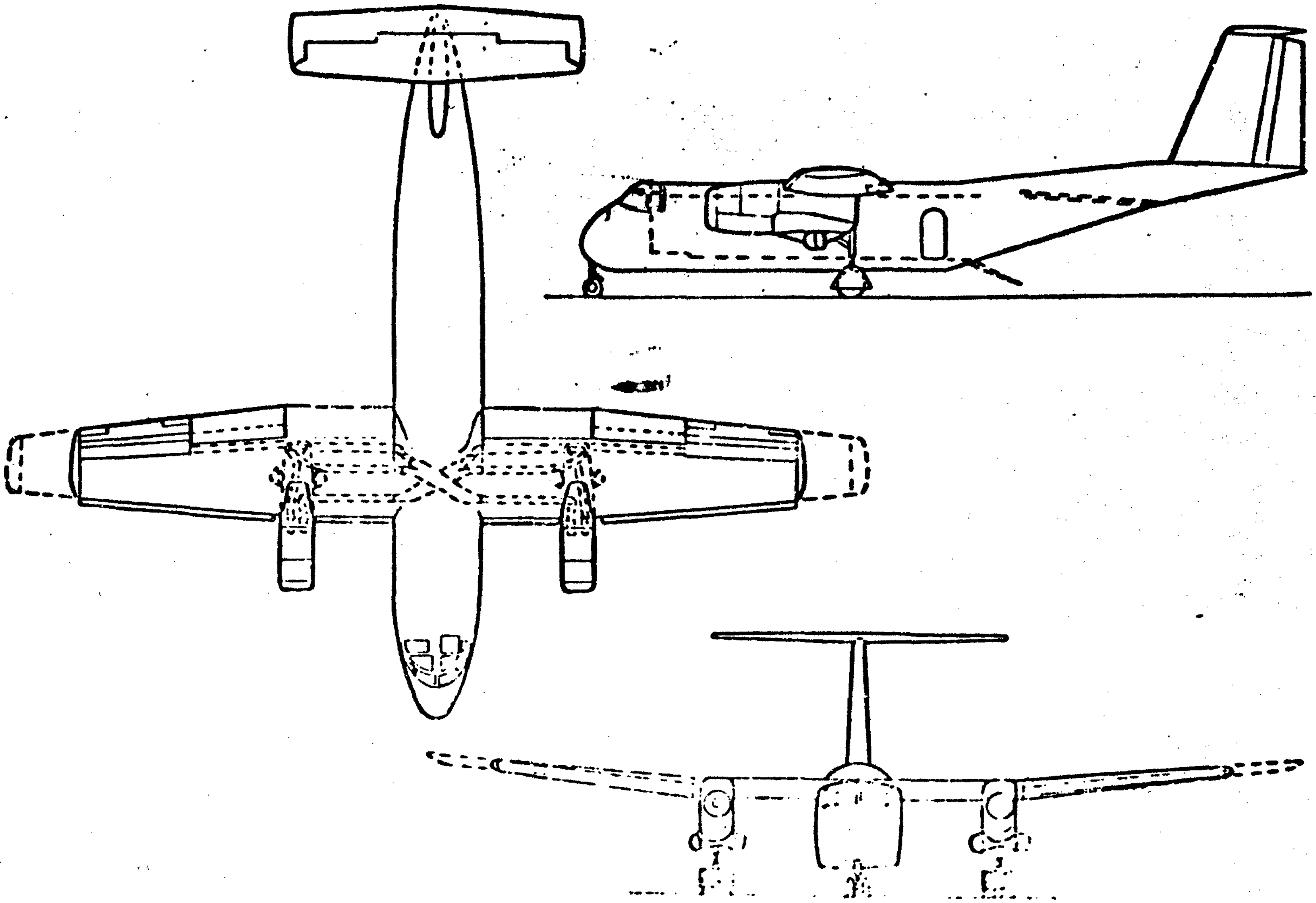

Figure G-10. Augmentor-wing flight-test vehicle.

APPENDIX H

FLOATING ISLANDS AND BARE BASES

by

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SUMMARY

Currently, forward bases, at least above the direct-support level, are fairly static. These bases are a liability, both economically and politically. As we look ahead it can be seen that the political liability may become greater than it is today. There is current work in the development of semi-permanent portable forward bases. The "Bare Base" concept is one of these. In this concept, facilities are moved in rapidly and used. After use they can be collapsed, moved out, and reused.

As we look for solutions to the problems of bases, we come back to the basic fact that three quarters of the earth's surface is water. Perhaps the best place to locate these bases would be on this water. When one considers bases on the water, there are several alternatives. We can envision a fairly rigid forward base similar to the one shown in figure H-1. Most of us are acquainted with off-shore oil-drilling rigs. We could use a structure similar to this which could be floated into position and sunk to the bottom, whereupon it would become a rigid structure. You could envision a base such as this close to the shore, which could be utilized either as an air base or an ocean-going ship base. There are technical limitations to this, including those imposed by subsurface, tidal, and weather conditions. Cost is also a major factor.

There are many concepts for floating bases. It is interesting to note for example, that consideration has been given to using a floating base in the Hudson River as an airport. Figure H-2 shows a raft-type device which floats just above the surface of the water and has the width and length required for handling most aircraft. Another example is an air-cushion-type device in which air is trapped under the structure and used for buoyancy.

These are not new ideas. Man has been thinking about floating landing fields and floating ports for years. A strucuture was conceived in 1930 known as an Armstrong Ae~odrome. This structure was an all-steel structure with the joining devices floating well below the wave action.

We at Goodyear have an ongoing program in which we are looking at a floating base (it might be called a floating island). In this particular application, inflatable stabilizing columns are used. We are considering a laminated, rubberized material from which we will fabricate the columns and some of the supporting structure. A base designed in this manner could be transported to any water-covered area of the globe, inflated, erected, and used. We are in the final stages of this particular program. A preliminary design has been developed and evaluated (figure H-3). The columns are topped by a sandwich-type landing deck which is also portable and easily assembled where required. One might wonder about the material being proposed for the columns. We are testing a design that would be somewhat like a truck tire. It would be inflated to pressures up to 100 psi.

Returning to figure H-2, these are typical float configurations. You can see that for a zero sea sate, when the columns are submerged to a depth that would give stability, there is also the necessary flotation to support the deck above the water. The attenuators are on the bottom of the columns. These are filled with water to ballast them below the wave action. You can see from figure H-2 that when we get up to sea state 7 that this gets to be a large and complicated structure, with columns and attenuators up to 100 feet in length.

How can a structure like this be erected? One of the requirements is that all the components would be air transportable. Ideally, we should also be able to airdrop them. The island could be erected from conventional ships with erection platforms on their decks.

I am sure that all of you can envision innumerable problems, but I do not feel that anyone can find fault with the fact that a forward floating base which is not on foreign real estate does not have the political implications or require the negotiations necessary for a fixed land base. Further, this installation could be disassembled, folded up, and moved when no longer required.

We will soon begin the test program in which we will dynamically test models in a basin. From this, if the results are favorable, we will move forward to a large-scale model. This program is being carried out for the Navy.

For an installation 20 years in the future, it may be practical to combine the floating island with the "Bare Base" structures being built for the Air Force. Figure H-4 shows a bare base unit 8 feet high, 3 feet deep, and 13 feet wide which is air transportable. This unit is field erectable and folds out to a module 33 feet long. If one is aware of the Air Force's bare-base program, these structures are in use and are meeting with success. A kitchen unit is being developed and built with all equipment in the center portion so that when it is opened, it becomes a full-scale kitchen and dining area.

If you let your imagaination roam a bit, you can visualize a floating island with bare-base-support structures on the deck. This island could be used as a complete provisioning base on which the C-5 long-range aircraft could land and off-load provisions, stores, or troops. From this, STOL and VTOL type aircraft could move the materiel to its end user, the troops in the field.

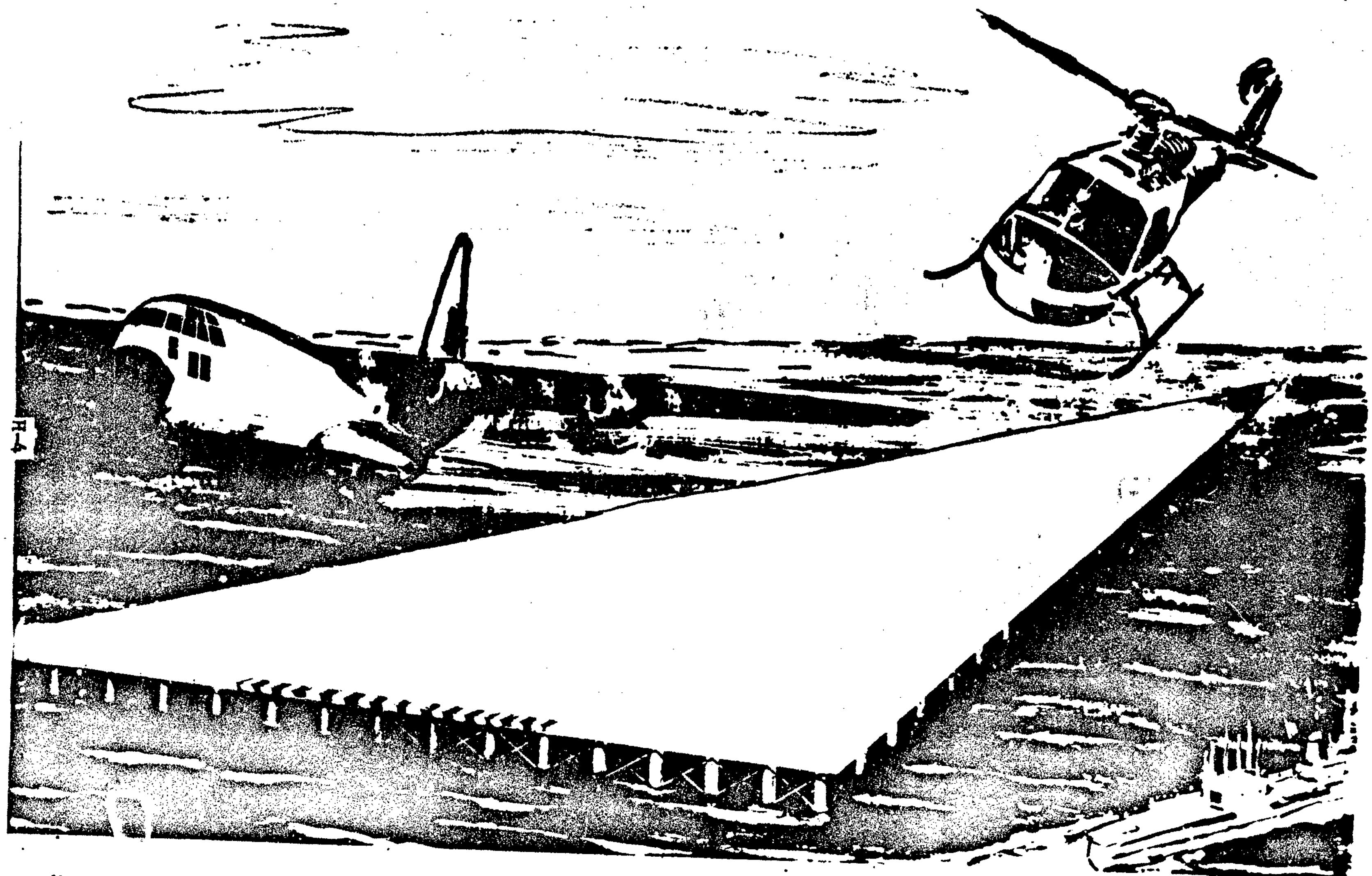

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Figure H-1. Artist's concept of a floating forward base.

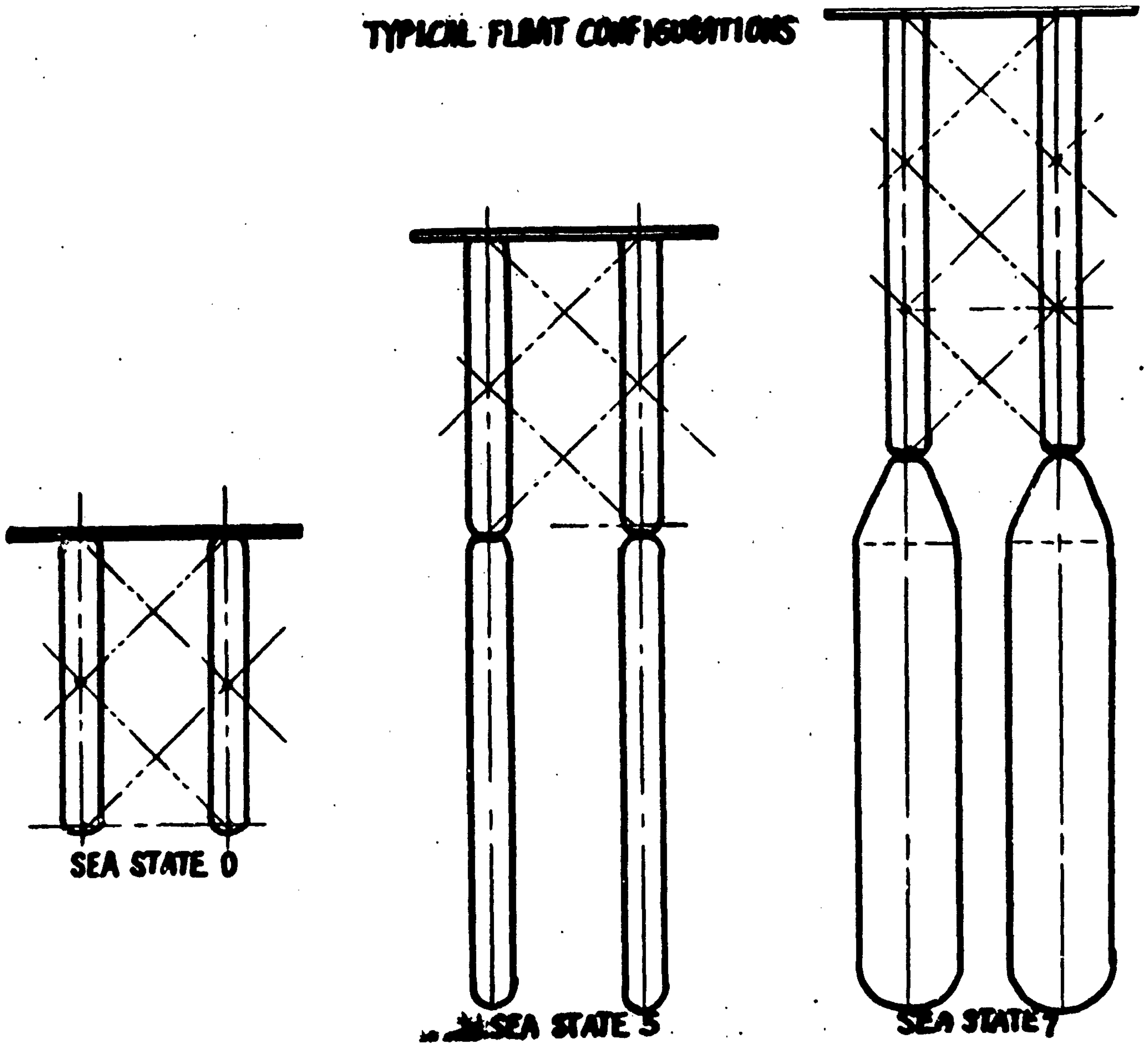

Figure H-2. Float configurations for a raft-type floating base.

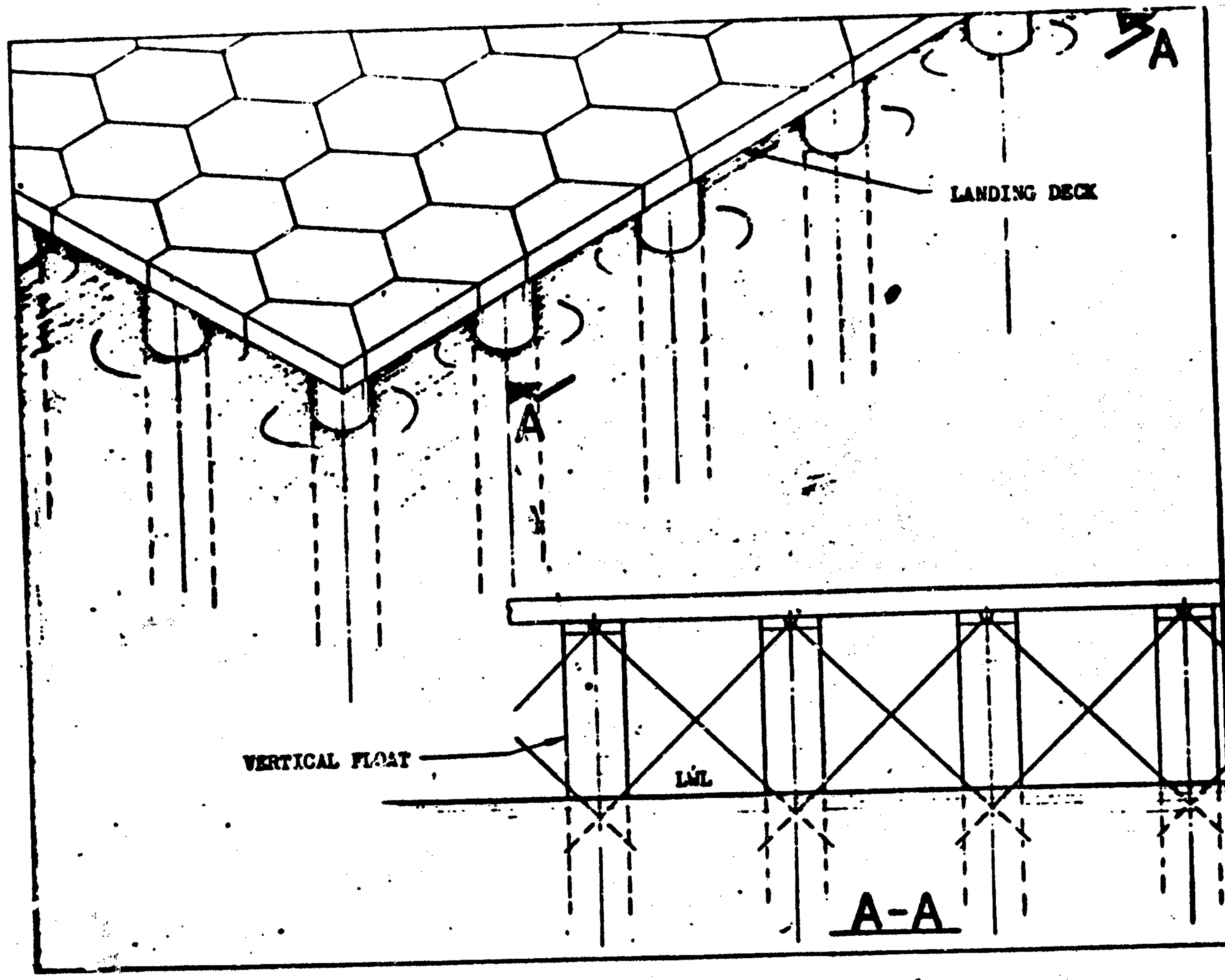

Figure H-3. Design of landing deck for a floating base.

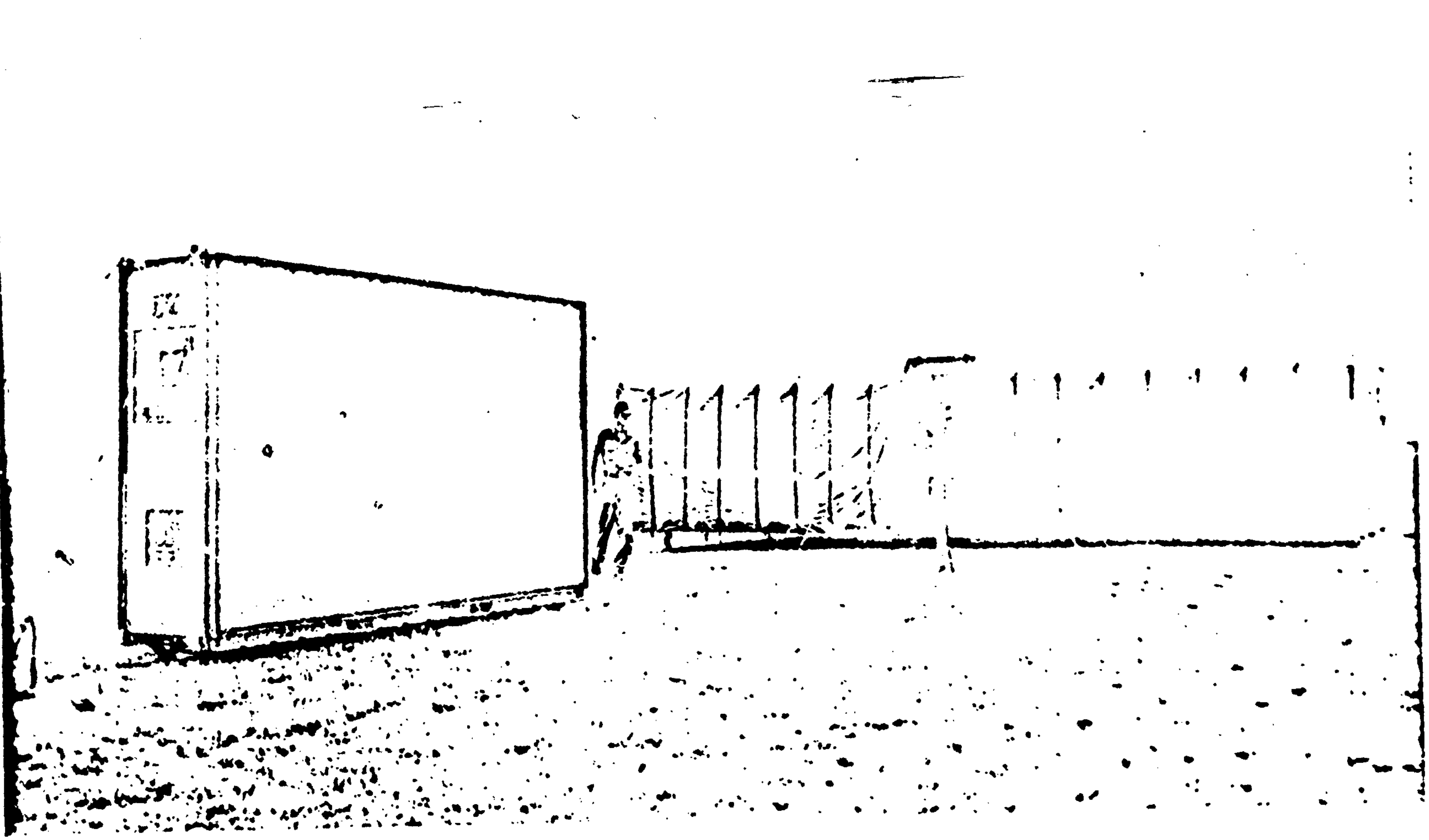

Figure H-4. Field erectable, "bare-base" facility.

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